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(12) **United States Patent**
Zhou et al.

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(45) **Date of Patent:** **May 23, 2023**

(54) **NUCLEOTIDE SEQUENCES AND
CORRESPONDING POLYPEPTIDES
CONFERRING MODULATED GROWTH
RATE AND BIOMASS IN PLANTS GROWN
IN SALINE CONDITIONS**

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(US)

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patent is extended or adjusted under 35
U.S.C. 154(b) by 40 days.

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division of application No. 16/275,537, filed on Feb.
14, 2019, now Pat. No. 10,428,346, which is a
division of application No. 15/487,287, filed on Apr.
13, 2017, now Pat. No. 10,233,460, which is a
division of application No. 13/663,204, filed on Oct.
29, 2012, now Pat. No. 9,637,756, which is a division
of application No. 12/282,342, filed as application
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No. 8,324,454.

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14, 2006.

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C12N 15/82 (2006.01)
C07K 14/415 (2006.01)
C12N 9/88 (2006.01)
A23K 10/30 (2016.01)
A23L 19/00 (2016.01)

(52) **U.S. Cl.**
CPC **C12N 15/8273** (2013.01); **A23K 10/30**
(2016.05); **A23L 19/00** (2016.08); **C07K**
14/415 (2013.01); **C12N 9/88** (2013.01);
C12N 15/8261 (2013.01); **C12Y 208/02015**
(2013.01); **A23V 2002/00** (2013.01); **Y02A**
40/146 (2018.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Dentons US LLP

(57) **ABSTRACT**

The present invention relates to isolated nucleic acid molecules and their corresponding encoded polypeptides able confer the trait of improved plant size, vegetative growth, growth rate, seedling vigor and/or biomass in plants challenged with saline conditions. The present invention further relates to the use of these nucleic acid molecules and polypeptides in making transgenic plants, plant cells, plant materials or seeds of a plant having plant size, vegetative growth, growth rate, seedling vigor and/or biomass that are improved in saline conditions with respect to wild-type plants grown under similar conditions.

12 Claims, 16 Drawing Sheets

Specification includes a Sequence Listing.

(56)

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Figure 1

SEQ-ID-NO-90-CLONE-554272	MSGCVLGLC	VGI GGCVCVV	HPISQ---PAS	CAAEPVLAPE	29
SEQ-ID-NO-92-CLONE-881632	LLLLLLVPLV	AAATAPCAHPA	YPNE---PPS	CAA-APVPE	41
SEQ-ID-NO-93-GI-50944095	LLLLLLLPLH	AAATPSAHPA			45
SEQ-ID-NO-80-CLONE-8686	FLFAVLSLS	SSLLA		DDPKPI	30
SEQ-ID-NO-84-CLONE-954851				DDLKPI	10
SEQ-ID-NO-85-CLONE-1064137	TLLSPLSLI	HAAISDAYPT	I PGT--APID	GGFSDCLKPI	47
SEQ-ID-NO-95-ANNOT-1494052	LLLLLLSPIS	TTASTAAYPT	I PGTI DTSVS	SSOPDNLPI	50
SEQ-ID-NO-90-CLONE-554272	ENENGRIF	MPAWESKDSL	GO-FLWLT RS	MANGSLANFS	76
SEQ-ID-NO-92-CLONE-881632	RREAHGCGRI	MPSWESGAGV	GO-FLWLPAS	MRNGSLANNS	90
SEQ-ID-NO-93-GI-50944095	RREAHGCGRI	MPSWESDGGV	GO-FLWLPAS	MRNGSRANNS	94
SEQ-ID-NO-80-CLONE-8686	RREYEGGKI	IPAWESSEGL	GKTFLRLAAS	MKNGSEFANVS	80
SEQ-ID-NO-84-CLONE-954851	ROEYGERKI	MPVWESSTEGV	KP-FLRLTTS	MKNQSLSNITS	59
SEQ-ID-NO-85-CLONE-1064137	RREYGEKGI	MPAWESKEGI	GR-FLWLAAS	MKNGSLANNS	96
SEQ-ID-NO-95-ANNOT-1494052	RNEI YGNCKI	MPVWDSKDGCL	GK-FLSLPAS	MKNGSLANNS	99
SEQ-ID-NO-90-CLONE-554272	QEKLPVHSCT	HYFHSGFDVD	SLDLLLLNGP	ALLVDVPRDI	126
SEQ-ID-NO-92-CLONE-881632	EMRMPHTHTGT	HYFDAGFDVD	TLDLDVNLNGP	ALLVDVPRDE	140
SEQ-ID-NO-93-GI-50944095	EMRLPHTHTGT	HYFDAGFDVD	SLDLEVLNGL	ALLVDVPRDD	144
SEQ-ID-NO-80-CLONE-8686	EMKLSVHSCT	NYYDAGFDID	SLDLQVLNGP	ALLVDVPRDK	130
SEQ-ID-NO-84-CLONE-954851	EMKLSVHTGT	KYYDAGFDSD	SLDLQVLHGP	ALLVDVPRDK	109
SEQ-ID-NO-85-CLONE-1064137	EMKI PHTHTGT	EYYDAGFDVD	SLDLQVLNGP	ALLVDVPRNK	146
SEQ-ID-NO-95-ANNOT-1494052	EMKLPHTHTGT	HYFDSGFDVD	TLDLEVLNGL	ALLVDVPRHS	149
SEQ-ID-NO-90-CLONE-554272	NI SAGVMKSL	FRTLNTVRRRL	MYQKEFDTSY	VGFTEDGANW	176
SEQ-ID-NO-92-CLONE-881632	NI TAKVMESL	FRTLNTDRNL	MWKKEFDTSY	VCFMKDGAQW	190
SEQ-ID-NO-93-GI-50944095	NI TAKMMESL	FRTLNTDRQL	MWKKEFDTSY	VGFMEDGAQW	194
SEQ-ID-NO-80-CLONE-8686	NI TAEVMESL	FRTSNTDKRL	MFKKEFDSSF	AGFMTDGAKW	180
SEQ-ID-NO-84-CLONE-954851	NI X-XVMKSL	FRTLNTDRRL	MFKKEFDSSF	AGFMMDGAKW	158
SEQ-ID-NO-85-CLONE-1064137	NI TAEVMKSL	FRTLNTDRRL	MFKKEFDTSY	VCFMKDGAQW	196
SEQ-ID-NO-95-ANNOT-1494052	NI TAEVMKSL	FRTLNTDRRL	MFKREFDRSY	VGFTKDGAKW	199

Figure 1 - continued

SEQ-ID-NO-90-CLONE-554272	VENTDI KLV	GI DYLSVAAY	DLI PAHLVF	LKRETI LVE	GLKDDVAAG	226
SEQ-ID-NO-92-CLONE-881632	VDNTDI KLV	GI DYLSVAAF	DDLI PSHLVL	ENRDI LVE	GLKLENI PG	240
SEQ-ID-NO-93-GI-50944095	VDNTDI KLV	GI DYLSVAAF	DDLI PSHLVL	KNRDI LVE	GLKLENI MPG	244
SEQ-ID-NO-80-CLONE-8686	VVENTDI KLI	GLDYLSFAAF	EESPAIHRVI	LKGRDI PVE	ALKLDGVEVG	230
SEQ-ID-NO-84-CLONE-954851	VVENTDI KLI	GLDYLSFAAY	EEAPEIHKFI	GERDI PVE	ALKLDGVEVG	208
SEQ-ID-NO-85-CLONE-1064137	VVDNTDI KLV	GV DYLSVAAY	DDLI PSHLVF	LKRETI LVE	GLKDDVKAG	246
SEQ-ID-NO-95-ANNOT-1494052	VVDNTDI KLV	GI DYLSVAAW	SDLI PSHLVF	EGRETI LVE	ALKLDDI QPG	249
SEQ-ID-NO-90-CLONE-554272	YTVHCLPLR	LAGAEGSPI R	CI LIK	251		
SEQ-ID-NO-92-CLONE-881632	YSLHCLPLR	LRGAEGSPI R	CI LIK	265		
SEQ-ID-NO-93-GI-50944095	YSLHCLPLR	LRGAEGSPI R	CI LIK	269		
SEQ-ID-NO-80-CLONE-8686	YSLHCLPLR	LVGAEGAPTR	CI LIK	255		
SEQ-ID-NO-84-CLONE-954851	YSLHCLPLR	LVGAEGAPTR	CI LIK	233		
SEQ-ID-NO-85-CLONE-1064137	YYSVHCLPLR	LVGAEGSPI R	CI LIS	271		
SEQ-ID-NO-95-ANNOT-1494052	YYSVHCLPLR	LVGAEGSPI R	CVLIK	274		

Figure 2

SEQ-ID-252	MGKRGKWFSA	VKKVFSSSDP	DGKEAKAQA	DKSKSKRRWP	FGSKHSEPS	50
SEQ-ID-NO-301-CLONE-228069	MGKKGKWFCA	VKKVFSPESK	EKKEERL	RR	KSAASNPA	37
SEQ-ID-NO-302-CLONE-335348	MGKKGKWFCA	VKKVFSPESK	EKKEE			25
SEQ-ID-NO-100-GI-56202321	MGKKGNMFSA	VKKVFSSSDP	DGREAKI EKA	DKSRRR	KMPFGKSK	45
SEQ-ID-NO-303-GI-54306075	MGKKGKWFCA	VKKVFSPESK	EKKEERL	RR	KLAASNPN	37
SEQ-ID-NO-312-CLONE-1727738	MGKKGKWFCA	VKKVFSPESK	EKKEERQ	RR	KSAASNPT	37
SEQ-ID-NO-298-CLONE-1792902	MGKKGKWFCA	VKKVFSPESK	EKKEERQ	RR	KSAASNPT	37
SEQ-ID-252	-I STVPIGAP	AVA-PLPSPP	A-T	-QPHSLEIKD	VNPVETDSEQ	89
SEQ-ID-NO-301-CLONE-228069	PMDLTPSTSL	EVNVSVPPPP	A-P	-PPVPRQIDE	VRVPEAEQEQ	78
SEQ-ID-NO-302-CLONE-335348						25
SEQ-ID-NO-100-GI-56202321	KSDPWTSTLV	AMPTSTAPPP	QPPPPPTHP	IQQPEEIKD	VKA VETDSEQ	94
SEQ-ID-NO-303-GI-54306075	PPDLTPSASL	EVNVSVPPPP	P	PPVQIQEE	VKMPEVEQEQ	77
SEQ-ID-NO-312-CLONE-1727738	PRDLTPSTSL	EVNVSVPPPP	A	PALHQIQEE	RAPEAEQEQ	77
SEQ-ID-NO-298-CLONE-1792902	PLDLTPSTSL	EVNVSVPPPP	A	PALHQIQEE	VRPEAEQEQ	77
SEQ-ID-252	NKHAYSVALA	SA--VAAEA	AAVAAQAAE	VVRLTAVTTA	APKMPVSSRE	136
SEQ-ID-NO-301-CLONE-228069	SKHVT-LEEA	PA--AAAPAQA		SV	PPCAPTE	107
SEQ-ID-NO-302-CLONE-335348						25
SEQ-ID-NO-100-GI-56202321	NKHAYSVALA	SA--VAAEA	AAVAAQAAE	VVRLTAVTTA	MPKSPVSSKD	141
SEQ-ID-NO-303-GI-54306075	SKHVT-VEAV	PEAVPVPAQT		SS	PPGVSSRE	106
SEQ-ID-NO-312-CLONE-1727738	SKHVT-VEEA	PA--APAQA		SV	PPGVPSE	103
SEQ-ID-NO-298-CLONE-1792902	SKHIT-VEEA	PA--APAQA		SV	PPGVPSE	103
SEQ-ID-252	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVDGNAVKR	QTAHFLQCIC	186
SEQ-ID-NO-301-CLONE-228069	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVEGNSVKR	QSASTLRCMO	157
SEQ-ID-NO-302-CLONE-335348						25
SEQ-ID-NO-100-GI-56202321	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVDGNAVKR	QTAHFLHCLIC	191
SEQ-ID-NO-303-GI-54306075	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVEGNSVKR	QAASTLRCMO	156
SEQ-ID-NO-312-CLONE-1727738	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVEGDSVRR	QSASTLRCMO	153
SEQ-ID-NO-298-CLONE-1792902	ELAAIKI QTA	FRGYLARRAL	RALRGLVRLK	SLVEGDSVRR	QSASTLRCMO	153

Figure 2 - continued

SEQ-ID-252
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 SEQ-ID-NO-302-CLONE-335348
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 SEQ-ID-NO-303-GI-54306075
 SEQ-ID-NO-312-CLONE-1727738
 SEQ-ID-NO-298-CLONE-1792902

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SRRVKLEEEK
 SRRAKMSEEN

QALQRQLQLK
 QALQRQLLLK

HQRELEKMKI
 QELENFRM

DEDWDHSHQS
 GENWDDSTQS

236
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 241
 204
 201
 201

SEQ-ID-252
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 SEQ-ID-NO-303-GI-54306075
 SEQ-ID-NO-312-CLONE-1727738
 SEQ-ID-NO-298-CLONE-1792902

KEQIEANLMM
 KEQIEASLIS

KQEAALRRER
 RQEAALRRER

ALAYAFSHQW
 ALAYAFSHQW

RNSGRITITP
 KSTSRSANPM

FTEPGNPNWG
 FVDPNNLQWG

286
 255
 25
 291
 254
 251
 251

SEQ-ID-252
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 SEQ-ID-NO-100-GI-56202321
 SEQ-ID-NO-303-GI-54306075
 SEQ-ID-NO-312-CLONE-1727738
 SEQ-ID-NO-298-CLONE-1792902

MSWMERWMTA
 MSWLERWMAA

RPWESR-AAA
 KPWEGRNG

SDKDP-KERA
 TDKESNIDRG

VTKNASISA
 SVKNMSLNLG

-YRVPVSRAI
 VGEGETKAF

333
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 SEQ-ID-NO-298-CLONE-1792902

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 NRRDSKLEK
 SIQRP
 NRRGSKPKS
 NRRDSKPEK
 NRRDSKPEK

ATPN-KSRP
 SPPTPKPARP
 SPPTPRPARP
 ATPN-KSRP
 SPPTPKTRP
 SPPTPKTRP
 SPPTPKTRP

PSRQSLSTPP
 ASRQSPSTPS
 TSRHSPSTPS
 PSRQSPSTPP
 ASRQSPSTPS
 ASRQSPSTPS
 ASRQSPSTPS

SKTPSASGKA
 ARVAPIPARR
 ARVAPIPARR
 SRVPSMTGK
 AKVSPIFAKK
 AKVAPIPARR
 AKVAPIPARR

RPASPRNSWL
 KSSTPKNGLS
 KSMTPKNGLS
 RPASPRNSWL
 KSATPKNGLS
 KSATPKNGLS
 KSMTPKNGLS

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Figure 2 - continued

SEQ-ID-252
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 SEQ-ID-NO-303-GI-54306075
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 SEQ-ID-NO-298-CLONE-1792902

YKEDDLRSIT
 QVDDDMRSVL
 QVDDDMRSVL
 YKEDDLRSIT
 QVDDDAKSVF
 HVDDDAKSVF
 HVDDDAKSVF

SI RSE RRRRQ
 SVQSERRRH
 SVQSERRRH
 SI RSE RRRRQ
 SVQSERRRH
 SVQSERRRH
 SVQSERRRH

STGG-GSVRD
 SIATSTMRD
 SIATSTVRD
 STGG-ASVRD
 SIATSTVRD
 SIATSTVQD
 SIATSTVRD

DIISLITSTP
 DESLASSPSL
 DESLASSPSL
 DIISLITSTPAL
 DESLASSPSV
 NESLASSPSL
 DESLASSPSL

PSYMQSIESA
 PSYMQSIESA
 PSYMQSIESA
 PSYMQSIESA
 PSYMAPTKSA
 PSYMQSIESA
 PSYMQSIESA

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 SEQ-ID-NO-312-CLONE-1727738
 SEQ-ID-NO-298-CLONE-1792902

RAKSRYSLL
 RAKSRI--A
 RAKSRLQGSA
 RAKSRYSLL
 RAKSRLQGSA
 RAKSRLQGSA
 RAKSRLQGSA

LT EKL E M P E
 TANGAETP E
 MANGAETP E
 LTRFE M P E
 MTDGAETP P E
 LTNAGAETP E
 LTNAGAETP E

RAPLAHSVVK
 KCGSA-GPVK
 KCGSF-GPAK
 RVPLVHSSIK
 KVASV-GSVK
 KCGSA-GPVK
 KCGSA-GPVK

KRLSFPVVEK
 KRLSFQGGAA
 KRLSFQGGTA
 KRLSFPVADK
 KKL SFQAGMA
 KRLSFQGGTA
 KRLSFQGGTA

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 P-----P
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 KVDPAITLKDI
 KVESAVKDI

APPOPEALV
 APPOPEALV
 APPOPEALV
 AEPPQPEALV
 VAPPOPEALV
 VAPPOPEALV
 VAPPOPEALV

ANGGCSK
 VNG--GSK
 VNG--GSK
 NG--GSK
 NG--GSK
 NG--GSK
 NG--GSK

PA
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 PVS
 NG--GSK
 NG--GSK
 NG--GSK

498
476
217
500
474
471
471

Figure 3

SEQ-ID-NO-106-CLONE-105319	MEAAITQRIO	YPSWVDCRKY	ECKPQRGLR	YSQQVKVDRR	F--RCISAR	48
SEQ-ID-NO-107-CLONE-463638	MDCKVANGIV	VSPRI GSERF	ARRTCGSRVY	SRRFRQDRL	P--VLMSAQL	4
SEQ-ID-NO-115-GI-76782196	MEAGVGLALO	SRAAGFGGSD	RRRSALYCGE	GRARI	--GSLRVAE	48
SEQ-ID-NO-113-GI-56805577	MDAGVGLRPR	PRAAWAG--	RRKPOGFPPA	TVPAVRI--DON	PARRPLVRS	42
SEQ-ID-NO-112-CLONE-749796						47
SEQ-ID-NO-114-CLONE-294723						0
SEQ-ID-NO-106-CLONE-105319	LQPERRIDQR	RAVSPAVSCS	DNNSA--LLE	TGSV--YPFDE	D--LKRKAAEE	95
SEQ-ID-NO-107-CLONE-463638	QDKTRNSNIWH	RTTALLEVSCS	YGNISASILE	SGSVRAPLDE	EELI LKNRSQE	44
SEQ-ID-NO-115-GI-76782196	PAVAKAAVWA	KTASLEVSCS	YKNFPASVLE	SGCIHAPFDD	ALI LKNKSQE	98
SEQ-ID-NO-113-GI-56805577	DAGSRSTDPI	RGSKPVAPLR	AKKSSG--G	HEILHNSVDE	ALLLKRKSEE	89
SEQ-ID-NO-112-CLONE-749796		RGASLRGLQC	HKSA--G	TEKVHYSADE	ALVLKOKAED	92
SEQ-ID-NO-114-CLONE-294723						0
SEQ-ID-NO-106-CLONE-105319	MKPYLNGRISM	YLVGMMGSGK	TTVCKLMSKV	LGYTFFDDEIT	LIEQAMNGTIS	145
SEQ-ID-NO-107-CLONE-463638	QPYLNGRCI	YLVGMMGSGK	TTVCKI MSQV	LGYSFQDSDA	VEEEMVGNNS	94
SEQ-ID-NO-115-GI-76782196	EPYLSGRCI	YLVGMMGSGK	TTVKGVL SQV	LSYAFFDSDIT	LVEQDM DANS	148
SEQ-ID-NO-113-GI-56805577	MLFYLNGRCI	YLVGMMGSGK	STVCKI M SEV	LGYSFFDSDK	LVEQAVGMPIS	139
SEQ-ID-NO-112-CLONE-749796	MLPYLNDRCV	YLVGMMGSGK	TTVCKI I AEV	LGYSFFDSDK	LVEQSVGI PS	142
SEQ-ID-NO-114-CLONE-294723		MMGSGK	TTVCKI L SEV	LGYSFFDSDK	LVEKAVGI SS	36
SEQ-ID-NO-106-CLONE-105319	VAEIVFHGGE	NFFRIGKETDA	LKKLSSRYQV	VVSTGGGAVI	RPI NWKYMHK	195
SEQ-ID-NO-107-CLONE-463638	VADI FKQHGGE	TFFRNKETEY	LHKLSLMHQL	VI STGGGAVI	RPI NWKYMHK	144
SEQ-ID-NO-115-GI-76782196	VAEIVNLYGE	GFFRDKETEY	LRKLSLMHRL	VVSTGGGAVV	RPI NWKYMQK	198
SEQ-ID-NO-113-GI-56805577	VAQIFKVHSE	AFFRDNESEV	LRDLSSMKRL	VVATGGGAVI	RPVNWKYMKK	189
SEQ-ID-NO-112-CLONE-749796	VAEIVQVHSE	AFFRDNESEV	LRDLSSMHRL	IVATGGGAVI	RPI NWSYMKK	192
SEQ-ID-NO-114-CLONE-294723	VAEIVQLHSE	TFFRDNESEV	LTDLSSMHRL	VVATGGGAVI	RPI NWSYMKK	86
SEQ-ID-NO-106-CLONE-105319	GISI WLDVPL	EALAHRI AAV	GTIDSRPLLHD	ESGDAYSVAF	KRLSAI WDER	245
SEQ-ID-NO-107-CLONE-463638	GVSVWLDVPV	EALAQRI AAV	GTNSRPLLHY	EAGDPYTRAF	MRLSALFEER	194
SEQ-ID-NO-115-GI-76782196	GISVWLDVPL	EALARRI AAV	GTCSRPLLLHH	DSGDAITKTF	MRLTSLMEER	248
SEQ-ID-NO-113-GI-56805577	GLSVWLDVPL	DALARRI AAV	GTASRPLLDQ	PSGDPYTMAF	SKLSMLAEQR	239
SEQ-ID-NO-112-CLONE-749796	GLTI WLDVPL	DALARRI AAV	GTASRPLLHQ	ESGDPYAKAY	AKLTALFEQR	242
SEQ-ID-NO-114-CLONE-294723	GLTVWLDVPL	DALARRI AAV	GTASRPLLHQ	ESGDPYAKAY	AKLTSLFEQR	136

Figure 3 - continued

SEQ-ID-NO-106-CLONE-105319	GEAYTNANAR	VSLENI AAKR	CYKNVSDLTP	TEI C	EAF EQ	MLSFLEKEET	295
SEQ-ID-NO-107-CLONE-463638	GEAYANANAR	VSLKNI A KL	GKRDVSELSP	TDI AI	EAL EO	DNFL KEGG	243
SEQ-ID-NO-115-GI-76782196	SEAYANANAR	VSLEDVAAKL	GH RDVSN LTP	TAI AI	EAL EO	EGFL KEEN	297
SEQ-ID-NO-113-GI-56805577	GDAYANADVR	VSLEI ASKQ	GHDDVSKLTP	TDI AI	ESF HK	ENFV EHT	288
SEQ-ID-NO-112-CLONE-749796	MDSYANADAR	VSLENI ALKQ	GHNDVNLTP	SI AI	EAL LK	MESFL TEKA	291
SEQ-ID-NO-114-CLONE-294723	MDSYANADAR	VSLEHI ALKQ	GHNDVTI LTP	SI AI	EAL LK	MESFL TEKT	185
SEQ-ID-NO-106-CLONE-105319	ME PDGDL	---	---	---	---	---	303
SEQ-ID-NO-107-CLONE-463638	GRYAEC	---	---	---	---	---	249
SEQ-ID-NO-115-GI-76782196	GD FAL	---	---	---	---	---	302
SEQ-ID-NO-113-GI-56805577	V DNPVGD SQA	DSRAQRI QTL	---	---	---	---	308
SEQ-ID-NO-112-CLONE-749796	MVRN	---	---	---	---	---	295
SEQ-ID-NO-114-CLONE-294723	MVRN	---	---	---	---	---	189

Figure 5

SEQ-ID-NO-143-CLONE-1272732	AGRR	MVAVD	EGEESL	HALN	WCL	ANV	VSPA	GGDT	LVL	VHA	50
SEQ-ID-NO-139-CLONE-684584	MAAQ	APPP	ESEC	SHYAL	WAL	RNL		APRR	LIL	FTV	46
SEQ-ID-NO-142-CLONE-1059727		MVAID	DSDC	SKHALR	MTL	SYL	KDS	ADSD	LIL	FA	35
SEQ-ID-NO-134-ANNOT-1486744		MVI	ESEY	SYHSFM	WV	DNL	KEF	TESP	LVI	LAA	35
SEQ-ID-NO-132-CLONE-2767		MKN	SY	DL	WAL	ENQ	KDT	ESSK	VY	FAK	39
SEQ-ID-NO-143-CLONE-1272732	RRR	PM	Y	AA	MS	SAG		Y	MM	TS	90
SEQ-ID-NO-139-CLONE-684584	QPF	PL	S	L	PV	SP	LG	P	S	V	89
SEQ-ID-NO-142-CLONE-1059727	QP	LD	S	S	VY	AS	SY	A	AP	E	75
SEQ-ID-NO-134-ANNOT-1486744	L	P	AP	NCK	F	FY	GA	Q	F	G	83
SEQ-ID-NO-132-CLONE-2767	QP	NS	F	P	VT	P	T	I	FY	P	89
SEQ-ID-NO-143-CLONE-1272732	KRV	CAD	H	PH	KV	ET	VE	SS	GD		139
SEQ-ID-NO-139-CLONE-684584	KAI	CAEH	GV		DA	ET	VI	EV	ED		137
SEQ-ID-NO-142-CLONE-1059727	TKI	CAES	GV		TP	K	Y	ME	F	GN	123
SEQ-ID-NO-134-ANNOT-1486744	VNI	CASR	GV		KA	ET	LE	AGE			132
SEQ-ID-NO-132-CLONE-2767	KKI	CL	NH	GI	KA	ET	FT	NV	GD		135
SEQ-ID-NO-143-CLONE-1272732		FL	GS		V	S	NH	C	A	Q	162
SEQ-ID-NO-139-CLONE-684584		F	FL	GS	V	S	NY	C	S	H	160
SEQ-ID-NO-142-CLONE-1059727		T	FL	GS	V	S	NY	C	N	K	146
SEQ-ID-NO-134-ANNOT-1486744	L	G	N	F	V	T	S	K	I		182
SEQ-ID-NO-132-CLONE-2767					C	T	Q	N	I	T	150
SEQ-ID-NO-143-CLONE-1272732	P	K	E								165
SEQ-ID-NO-139-CLONE-684584	K	E									162
SEQ-ID-NO-142-CLONE-1059727	K	A									148
SEQ-ID-NO-134-ANNOT-1486744	Y	Q	K	H							186
SEQ-ID-NO-132-CLONE-2767	L	R	K	D							154

Figure 6

SEQ-ID-NO-151-GI-50944591	MAIHSTISAPA	APAFSAFPLA	AANRFPICASA	TSNITCAFLA	EHLTREGMFF	50
SEQ-ID-NO-152-CLONE-1551032	MAT-APPAAC	LRAPCSSPAA	VARRLGA---	-GGPSLRKRH	CAPA PVA AAC	45
SEQ-ID-NO-146-CLONE-16403	MAVSSLSTRC	-GGFSPTLS	HKTEILC---	-PNPSL-KAC	CLLSSGKAD	43
SEQ-ID-NO-147-CLONE-611156	MVVSSESLSL	-SWISPCLS	HKLNLPH---	-TN-CLPRNI	ATSSSNVFC	41
SEQ-ID-NO-149-ANNOT-1464944	MAISSLSL	-SWASTLS	QKLSVPG---	-SNEILPRVA	AFSGNNSVTC	42
SEQ-ID-NO-151-GI-50944591	DLIQ--SKR	EAEER-SRRR	MLLAAGAAAF	LSPNPAAVA	AEA KKGFLPV	96
SEQ-ID-NO-152-CLONE-1551032	GPAPRLDNI	EAVC-SVRR	RVLVAGAAAF	LSPNPAAFA	AEA KKGFLPV	94
SEQ-ID-NO-146-CLONE-16403	SSES--TYQK	GSGNNKRRQ	ALVCGTILVA	TSLPATLLLA	EEIPKSYSPF	91
SEQ-ID-NO-147-CLONE-611156	ELD--TIPS	GESHCRRRP	LLLCIGALTA	NLQPTNLVFA	QEKPDYRAF	87
SEQ-ID-NO-149-ANNOT-1464944	TAE--ATFN	EESNC-KRRL	LLLVGALTT	SLVPIANFLFA	EEIPKNYTSE	88
SEQ-ID-NO-151-GI-50944591	TDKKDGYSFL	YDFGWOEVVV	QGQDKVYKDV	I EPLESVSMN	TTPTSKQDIR	146
SEQ-ID-NO-152-CLONE-1551032	VDKKAQYSFL	YDFGWEEVAV	QGQDKVYKDV	I EPLESVSMN	SIPTSKEDIR	144
SEQ-ID-NO-146-CLONE-16403	VDREDCYSYV	YPSDWREFDF	RAHDSAFKDR	YLQLOQNRVR	FIPTKNDIR	141
SEQ-ID-NO-147-CLONE-611156	VDYEDGYSYV	YPI DWKEFDF	RAHDSAFKDR	YLQLOQNRVR	FIPTKNDIR	137
SEQ-ID-NO-149-ANNOT-1464944	VDYEDGYSYV	YPSDWDFDF	RGHDSAFKDR	TQLOQNRVR	FIPTKNDIR	138
SEQ-ID-NO-151-GI-50944591	ELGPPDQVAE	ALIRKVLAAP	TQTKKLEAK	ENDVDGRTIYY	TFEFTAQAPN	196
SEQ-ID-NO-152-CLONE-1551032	DLGPPDKVAE	ALIKKVLAPS	TQTKKLEAK	ENDVDGRTIYY	TFEFTAQAPN	194
SEQ-ID-NO-146-CLONE-16403	EVGPMEEVYV	DLVKHKFAAP	NQVATYDMK	ERVEEDGKNYY	TFEYGLRTP	191
SEQ-ID-NO-147-CLONE-611156	DLGPMEEVYV	DLVKHRYAAP	NQRPTNDMQ	EKTIDGKHYY	TFEYLTSPN	187
SEQ-ID-NO-149-ANNOT-1464944	ELGPMEEVYV	DISHMQEIMN	VKLSNFEEN	QKTVEGKNYY	TFEYLTSPN	185
SEQ-ID-NO-151-GI-50944591	FTRHALGAI A	IANGKFYTLT	TGANERRWEK	KDRLHTVVD	SFKIEAREVR	246
SEQ-ID-NO-152-CLONE-1551032	YTRHALGAI V	IANGKFYTLT	TGANERRWEK	MKDRHTVVD	SFKIENRI---	242
SEQ-ID-NO-146-CLONE-16403	YATTSFATVA	VGNRYTYTLI	VGANERRWRK	VKKQLQVVAD	SFKI LQI---	238
SEQ-ID-NO-147-CLONE-611156	YSSASFATI A	IANGRYTYTLI	VGANERRWRK	FRDQLKVVAD	SFRLLDI---	234
SEQ-ID-NO-149-ANNOT-1464944	YSSVSFATLV	IANGRYTYTLI	VGANERRWRK	YRSQKVVAD	SFKVLDI---	232
SEQ-ID-NO-151-GI-50944591	FNGKREHGS	Y				257
SEQ-ID-NO-152-CLONE-1551032	---	---				242
SEQ-ID-NO-146-CLONE-16403	---	---				238
SEQ-ID-NO-147-CLONE-611156	---	---				234
SEQ-ID-NO-149-ANNOT-1464944	---	---				232

Figure 7

SEQ-ID-NO-168-CLONE-1064128	ATVFRDAGV	STPEADEA	KKYDEAR	27
SEQ-ID-NO-161-CLONE-703785	M	MASPOSSS	SHKEYDQLL	29
SEQ-ID-NO-169-GI-77552975				0
SEQ-ID-NO-160-GI-68067679				2
SEQ-ID-NO-163-GI-1706738				2
SEQ-ID-NO-154-CLONE-3964	MEASKEAHL	PNYMKDDN	VSOETK	44
SEQ-ID-NO-164-GI-342004	MESSSV	PVYLKDN	TQETR	20
SEQ-ID-NO-157-ANNOT-1448303	MVLNHF	TKNQANDNGE	DLERTNECK	26
SEQ-ID-NO-168-CLONE-1064128	RHPGWCITL	PIMVSSMVAE	QHFEARGTDV	77
SEQ-ID-NO-161-CLONE-703785	HHPDGMYAET	PAVYNA MVI K	RHLKACD TDV	77
SEQ-ID-NO-169-GI-77552975				14
SEQ-ID-NO-160-GI-68067679	YKYDAMNHQ	EFLEGR LSE	QKFKAHFNDV	52
SEQ-ID-NO-163-GI-1706738	YKYQDVWVHQ	EFLEGRMLSE	QTFKAHFNDV	52
SEQ-ID-NO-154-CLONE-3964	YNYKGCWYYP	NTLQAVLDVQ	KHFKPRDTDI	91
SEQ-ID-NO-164-GI-342004	YQFEGWQIQ	ALVQGI VNCQ	KHFEANDSDV	67
SEQ-ID-NO-157-ANNOT-1448303	YKYKGF WCQP	KEIQAI SFQ	KHFEPRD TDV	73
SEQ-ID-NO-168-CLONE-1064128	AHRTDDTSSS	LLRQLASHNS	HQLVPFLEAQ	127
SEQ-ID-NO-161-CLONE-703785	LRRTADGP	AAALAAHSP	HQLIPFLEVQ	125
SEQ-ID-NO-169-GI-77552975	LHRRAD	ELLAHSP	HQLISFLESO	57
SEQ-ID-NO-160-GI-68067679	ITREKFD DST	SPLTTMP	HDCIPLLEKD	100
SEQ-ID-NO-163-GI-1706738	ITREKFD DST	SPLTTMP	HDCIPLLEKD	100
SEQ-ID-NO-154-CLONE-3964	VHREKYRGT P	QTHPLLQNP	HDLVPFLEVE	141
SEQ-ID-NO-164-GI-342004	IHRKFPVSG	KHPLLVTNP	HSLVPYLEGD	116
SEQ-ID-NO-157-ANNOT-1448303	LNRKKAIS	NDHPLL VSNP	HDLAPFF EYK	123
SEQ-ID-NO-168-CLONE-1064128	THI PAESLPP	SVVASGCKVV	YLCRDPKDCF	177
SEQ-ID-NO-161-CLONE-703785	THI PSRSLPE	SVVASGCKVV	YLCRDPKDCF	175
SEQ-ID-NO-169-GI-77552975	THI PSQSLPD	SVVASGCKVV	YLCRDPKDCF	107
SEQ-ID-NO-160-GI-68067679	THFYKSLPE	SARTSNCKI V	YIYRNMKDVI	147
SEQ-ID-NO-163-GI-1706738	THEFYKSLPE	SARTSNCKI V	YIYRNMKDVI	147
SEQ-ID-NO-154-CLONE-3964	THMHLQALRE	ATTKACKTV	YVCRGKIDTF	190
SEQ-ID-NO-164-GI-342004	THLTHHSLPV	SIKSSSCKI I	YCRNPKDMF	165
SEQ-ID-NO-157-ANNOT-1448303	THI PFA SLQD	SIKSNCR I I	YICRNPF DTF	173

Figure 7 - continued

SEQ-ID-NO-168-CLONE-1064128	VSLWHFVWIKF	T-----PWD	DEAHGRFCEG	VSLYGFWEH	VLSYWRWHVD	222
SEQ-ID-NO-161-CLONE-703785	VSLWHFVWRF	AP---SPWDL	GEALQQFCDG	VSLFGPFWEH	VLGYWRWHVE	222
SEQ-ID-NO-169-GI-77552975	VSLWHFVWRF	M---PWN	DDAHRQFCNG	VSLFGPFWEH	VLSYWRWHVE	152
SEQ-ID-NO-160-GI-68067679	VSYHFLRQI	VKLSVEEAPF	EEAFDEFCCG	VSSCGPYWEH	KGYWKAASLE	197
SEQ-ID-NO-163-GI-1706738	VSYHEL RQI	VKLSVEEAPF	EEAVDEFCCG	VSSCGPYWEH	LGYYWKAASLE	197
SEQ-ID-NO-154-CLONE-3964	VSGWYRNMML	HRTKMDQATF	ELMFDAYCRG	VLLYGPYWEH	VLSYWKASLE	240
SEQ-ID-NO-164-GI-342004	VSIWHFCRKL	APEKTAEPPI	ETAVAAFCCKG	KFI GPPFWDH	VLEYWYKESLK	215
SEQ-ID-NO-157-ANNOT-1448303	SSMTFSNKL	RSETVPPPLL	EETFKMYCEG	VVGF GPPFWDH	MLGYWKEASLE	223
SEQ-ID-NO-168-CLONE-1064128	RPGQVLF LTY	EELSA DPLSQ	LRRLAEFI GR	PFTPGEQEAG	MDREI AEACA	272
SEQ-ID-NO-161-CLONE-703785	RPEQVLF LTY	EELAADL LGG	LKRLAAFLGR	PFTSEEREAR	MDREI VEACA	272
SEQ-ID-NO-169-GI-77552975	RPSEVLF LTY	EELAADL LGH	LRRLAEFVGR	PFTTEEQDAR	MDRKI VEI CA	202
SEQ-ID-NO-160-GI-68067679	KPEI F LFLKY	EDMKKDPVPS	VKKLADFI GH	PFTPKEEEAG	VI EDI VKLCS	247
SEQ-ID-NO-163-GI-1706738	KPEI F LFLKY	EDMKKDPVPS	VKKLADFI GH	PFTPKEEEAG	VI ENI I KLCS	247
SEQ-ID-NO-154-CLONE-3964	AKENVLFMKY	EELTEPRVQ	VKRLAEFL EC	PFTKKEEESG	SVEEI LKLCS	290
SEQ-ID-NO-164-GI-342004	NPINKVLFVTY	EELKKQTEVE	VKRI AEFI GC	GFTA EEE	VSEI VKLCS	261
SEQ-ID-NO-157-ANNOT-1448303	RQDKVLF LKY	EDMKADVT FY	LKKI AKFLGC	PFSMEEREG	VVEKI ASLCS	273
SEQ-ID-NO-168-CLONE-1064128	MKSMVNIQEVN	QSRTEI EIVE	MPJ PNGI FFR	RGVVG DWVNY	LTPEMAGRID	321
SEQ-ID-NO-161-CLONE-703785	MESLAGLEVN	RSGKTDMT E	SSVANNI FFR	RGVVG DWKNH	LTPEMARRI D	321
SEQ-ID-NO-169-GI-77552975	MESLSGLEVN	RSGMNFTK	KDMPNNI SFR	RGVVG DWRNH	LTPEMARRI D	251
SEQ-ID-NO-160-GI-68067679	FEKLSSEVN	KSGMHRPEEA	HSI ENRL YFR	KGKGDWKNY	FTDEMFKI D	297
SEQ-ID-NO-163-GI-1706738	FEKLSSEVN	KSGMHRPEEA	HSI ENRL YFR	KGKGDWKNY	FTDEMFKI D	297
SEQ-ID-NO-154-CLONE-3964	LRNLSNLEVN	KNGTTR	I GVD SQVFFR	KGEVGDWKNH	LTPOMAKIFD	336
SEQ-ID-NO-164-GI-342004	FESLSSEVN	RQKLP	NGI ESNAFFR	KGEI GWRDI	LSES ADVI D	307
SEQ-ID-NO-157-ANNOT-1448303	FEKMNLEVN	KSGRS	TNFKHLFR	KAEVGDWVNY	LSPSMVKOLIS	319
SEQ-ID-NO-168-CLONE-1064128	EITKSKFECS	GLMLPKTISE	I SKI	---	---	345
SEQ-ID-NO-161-CLONE-703785	EITDSKFRGS	GLALTPATAD	QN	---	---	343
SEQ-ID-NO-169-GI-77552975	EITVKFKFGS	GLLLHPPFLO	VKRELNEL	---	---	279
SEQ-ID-NO-160-GI-68067679	KLI DEKLGAJ	GLVLK	---	---	---	312
SEQ-ID-NO-163-GI-1706738	KLI DEKLGAJ	GLVLK	---	---	---	312
SEQ-ID-NO-154-CLONE-3964	EII DYRLGDS	GLIFO	---	---	---	351
SEQ-ID-NO-164-GI-342004	RTTEQKFGGS	GLKFSS	---	---	---	323
SEQ-ID-NO-157-ANNOT-1448303	QLIEEKLGG	GGVQAAAAA	SSSSSVI KKK	FELQRYGENK	NTNVN	364

FIGURE 8

SEQ-ID-NO-172-CLONE-965405	MSADSSNAI	DVIGKLGSDL	NVNSDGEDAA	DNDSSKITLT	PAPAVCLVR	49
SEQ-ID-NO-173-CLONE-5367	MAANDSSNAI	DIIGNLDSDS	NLNTDGDAT	DNDSSKALVT	PAPAVCLFR	50
SEQ-ID-NO-174-GI-79537394	MAAENSNAI	NVDITSLDSDS	KPNRDANDMT	DHDSSSKALV	PAPAVCLVR	50
SEQ-ID-NO-175-GI-9758183	MAAENSNAI	NVDITSLDSDS	KPNRDANDMT	DHDSSSKALV	PAPAVCLVR	50
SEQ-ID-NO-176-CLONE-1060894	MAAENPISNGM	DVDITSLASDS	NDNRKASDLT	NHDSS-MALT	VPSIAVCLCR	49
SEQ-ID-NO-179-ANNOT-1494390	MATANSPINTS	NNSDSDVEDP	NPNPSSN-N	NNASITPSAE	SSTPSVCLIR	48
SEQ-ID-NO-177-CLONE-639280	MAAIR-SEINES	DGDVG---	NPAEGGS---	---SLSLPPPL	AAGPAVCVLR	39
SEQ-ID-NO-172-CLONE-965405	FAGDAAAGGAV	MGSI FGYGSG	LFKKGFKGS	FADAGQSAKT	FAVLSGVHSL	99
SEQ-ID-NO-173-CLONE-5367	FAGDAAAGGAV	MGSI FGYGSG	LFKKGFKGS	FADAGQSAKT	FAVLSGVHSL	100
SEQ-ID-NO-174-GI-79537394	FAGDAAAGGAF	MGSVFGYGSG	LFKKGFKGS	FVDAGQSAKT	FAVLSGVHSL	100
SEQ-ID-NO-175-GI-9758183	FAGDAAAGGAF	MGSVFGYGSG	LFKKGFKGS	FVDAGQSAKT	FAVLSGVHSL	98
SEQ-ID-NO-176-CLONE-1060894	FAGDAAAGGAV	MGSI FGYGSG	LFKKGFKGS	FADAGQSAKN	FAI LSGVHSL	99
SEQ-ID-NO-179-ANNOT-1494390	FAGDAAAGGAF	MGSI FGYGSG	LFKKGFKGS	FVADAGQSAKT	FAVLSGVHSL	98
SEQ-ID-NO-177-CLONE-639280	SAGDFAGGAF	VGSI FGYGSG	LSKKGFKGS	LGNAQSASAKS	FAVLSGVQSL	89
SEQ-ID-NO-172-CLONE-965405	VVCLLKQLRG	KDDAI NVGVA	GCCTGLALSF	PGAPQALLQS	CLTFGAFSFI	149
SEQ-ID-NO-173-CLONE-5367	VVCLLKQLRG	KDDAI NVGVA	GCCTGLALSF	PGAPQALLQS	CLTFGAFSFI	150
SEQ-ID-NO-174-GI-79537394	VVCLLKQLRG	KDDAI NVGVA	GCCTGLALSF	PGAPQAMLQS	CLTFGAFSFI	150
SEQ-ID-NO-175-GI-9758183	VVCLLKQLRG	KDDAI NVGVA	GCCTGLALSF	PGAPQAMLQS	CLTFGAFSFI	148
SEQ-ID-NO-176-CLONE-1060894	VVCLLKQLRG	KDDAI NVGI A	GCCTGLALSY	PGAPQAMLQS	CVTFGAFSFI	149
SEQ-ID-NO-179-ANNOT-1494390	VVCLLKQLRG	KDDAI NVGVA	GCCTGLALSF	PGAPQALLQS	CLTFGAFSFI	148
SEQ-ID-NO-177-CLONE-639280	VVCLLKQLRG	KDDAI NVGI A	GCCTGLALSF	PGAPQALLON	CAIFAFSFI	139
SEQ-ID-NO-172-CLONE-965405	EGLNKRQTA	LAHSVSLR-H	QTGNFGDHQ	RPLQLSLALP	HEEI KGFHS	197
SEQ-ID-NO-173-CLONE-5367	EGLNKRQTA	LAHSVSLR-H	QTGLFQDHH-	RALPLSLALP	PEEI KGAFS	198
SEQ-ID-NO-174-GI-79537394	EGLNKRQTA	LAHSVSFR-Q	QTRSP---QH	DLPLLSLAI P	HDEI KGAFS	196
SEQ-ID-NO-175-GI-9758183	EGLNKRQTA	LAHSVSFR-Q	QTRSP---QH	DLPLLSLAI P	HDEI KGAFS	194
SEQ-ID-NO-176-CLONE-1060894	EGLNKRQTA	LAHSVSFR-HD	QTRSL---KD	DLP--SLALP	HEEI KGAFS	195
SEQ-ID-NO-179-ANNOT-1494390	EGLNKKQAA	LAHSI SSR-N	KCDYHS---KP	CPLALPLSVP	LPDELKGAFS	195
SEQ-ID-NO-177-CLONE-639280	MEGLNKKQTA	MAHTLTGN-A	LTFAH---DN	GAGVLPPLS	POSSMLPMLS	185

Figure 8 - continued

SEQ-ID-NO-172-CLONE-965405
 SEQ-ID-NO-173-CLONE-5367
 SEQ-ID-NO-174-GI-79537394
 SEQ-ID-NO-175-GI-9758183.
 SEQ-ID-NO-176-CLONE-1060894
 SEQ-ID-NO-179-ANNOT-1494390
 SEQ-ID-NO-177-CLONE-639280

S	F	C	K	S	L	T	K	P	K
S	F	C	K	S	L	A	K	P	R
S	F	C	N	S	L	T	K	P	K
S	F	C	N	S	L	T	K	P	K
S	F	C	K	S	L	T	K	P	K
F	F	C	K	S	L	R	K	P	K
P	H	A	R	P	W	S	P	S	
K	I								
K	F								
K	L	K	F	P	H	A	R		
K	L	K	F	P	H	A	R		
K	L	A	F	P	S	S	R		
S	A	N	F	P	A	A	A	P	
L	R	S	T	R	Q	H			

209
 210
 214
 212
 213
 214
 203

Figure 9

SEQ-ID-NO-304-CLONE-335348-T	ESNI DRGSV	KSMSLNL	GEI TKAFNR	RDSKLEKPS	PTPRARPIS	47
SEQ-ID-NO-305-CLONE-228069-T	ESNI DRGSV	KNMSLNL	GEI TKAFNR	RDSKPEKPS	PTPKPARPAS	49
SEQ-ID-NO-306-CLONE-375578-T	DP-KERAVT	KNASISA	RVPVSRAL	SIQRPAIT	PN-KSRPPIS	40
SEQ-ID-NO-307-CLONE-229668-T	ESNI DRGSV	KSMSLNL	GEI TKAFNR	RDSKLEKPS	PTPRARPIS	47
SEQ-ID-NO-308-GI-54306075-T	ESNL DRASA	KSASLNL	GEI TKAFNR	RDSKLEKPS	PTPKLTRPAS	47
SEQ-ID-NO-309-GI-56202321-T	DP-KDHYSI	KNPSISA	RTYMPRAI	SIQRPAIT	PN-KSRPPIS	40
SEQ-ID-NO-310-CLONE-1792902-T	ESNVDRGSV	KSMSLNL	GEI TKAFNR	RDSKPEKPS	PTPKLTRPAS	47
SEQ-ID-NO-311-CLONE-1727738-T	KESNI DRGSV	KSMSLNL	GEI TKAFNR	RDSKPEKPS	PTPKLTRPAS	48
SEQ-ID-NO-304-CLONE-335348-T	RHSPLTPSAR	VAPI PARRKS	VTPKNGLSQV	DDDARSVLSV	QSERPRRHSI	97
SEQ-ID-NO-305-CLONE-228069-T	RQSPSTPSAR	VAPI PARRKS	STPKNGLSQV	DDVVRSVLSV	QSERPRRHSI	99
SEQ-ID-NO-306-CLONE-375578-T	RQSPSTPSAR	TPSASGKARP	ASPRNSWLK	EDDLRSITSI	RSERPRRQSI	90
SEQ-ID-NO-307-CLONE-229668-T	RHSPLTPSAR	VAPI PARRKS	VTPKNGLSQV	DDDARSVLSV	QSERPRRHSI	97
SEQ-ID-NO-308-GI-54306075-T	RQSPSTPSAK	VSPI FAKKKS	ATPKNGLSQV	DDDAKSVFSV	QSERPRRHSI	97
SEQ-ID-NO-309-GI-56202321-T	RQSPSTPSR	VPSMTGKIRP	ASPRDSWLK	EDDLRSITSI	RSERPRRQSI	90
SEQ-ID-NO-310-CLONE-1792902-T	RQSPSTPSAK	VAPI PARRKS	VTPKNGLSHV	DDDARSVFSV	QSERPRRHSI	97
SEQ-ID-NO-311-CLONE-1727738-T	RQSPSTPSAK	VAPI PARRKS	ATPENGLSHV	DDDARSVFSV	QSERPRRHSI	98
SEQ-ID-NO-304-CLONE-335348-T	AT-STVRDDE	SLTSSPSLPS	YMPVPTESARA	KSRLOGSAMA	NGAETP-EKG	145
SEQ-ID-NO-305-CLONE-228069-T	AT-STMRDDE	SLASSPSLPS	YMPVPTESARA	KSRLOGSAMA	NGAETP-EKG	145
SEQ-ID-NO-306-CLONE-375578-T	GG-GSVRDDI	SLTSTPPLPS	YMQSTESARA	KSRLOGSAMA	EKLEVP-ERA	138
SEQ-ID-NO-307-CLONE-229668-T	AT-STVRDDE	SLTSSPSLPS	YMPVPTESARA	KSRLOGSAMA	NGAETP-EKG	145
SEQ-ID-NO-308-GI-54306075-T	AT-STVRDDE	SLASSPSVPS	YMAPTKSARA	KLRLOGSAVT	DGAETP-PEKV	146
SEQ-ID-NO-309-GI-56202321-T	GG-ASVRDDA	SLTSTPALPS	YMQSTESARA	KSRLOGSALT	DRFEVP-ERV	137
SEQ-ID-NO-310-CLONE-1792902-T	AT-STVRDDE	SLASSPSLPS	YMPVPTESARA	KSRLOGSALN	NGAETP-EKG	145
SEQ-ID-NO-311-CLONE-1727738-T	AT-STVODNE	SLASSPSLPS	YMPVPTESARA	KSRLOGSALT	NGAETP-EKG	146
SEQ-ID-NO-304-CLONE-335348-T	GSI-GPAKKR	LSFQGGTAA	ASP	MRRHSGPPKV	AP	180
SEQ-ID-NO-305-CLONE-228069-T	GSA-GPVKKR	LSFOGGAA	ASP	MRRHSGPPKV	SAVKDI	186
SEQ-ID-NO-306-CLONE-375578-T	PLAHSVVKKR	LSFVVEKPS	VVPTKPRER	VRRHSGPPKV	DPA	181
SEQ-ID-NO-307-CLONE-229668-T	GSI-GPAKKR	LSFQGGTAA	ASP	MRRHSGPPKV	AP	180
SEQ-ID-NO-308-GI-54306075-T	ASV-GSVKKK	LSFOAGMAP	PSP	MRRHSGPPKV	VKDI	186
SEQ-ID-NO-309-GI-56202321-T	PLVHSSJ KKR	LSFVADKPN	GEHADKMER	GRRHSGPPKV	DPA	180
SEQ-ID-NO-310-CLONE-1792902-T	SSA-GPVKKR	LSFQGGTAA	ASP	MRRHSGPPKV	SAVKDI	186
SEQ-ID-NO-311-CLONE-1727738-T	SSA-GPVKKR	LSFQGGTAA	ASP	MRRHSGPPKV	SAVKDI	187

Figure 9 - continued

SEQ.ID.NO.304.CLONE.335348.T
 SEQ.ID.NO.305.CLONE.228069.T
 SEQ.ID.NO.306.CLONE.375578.T
 SEQ.ID.NO.307.CLONE.229668.T
 SEQ.ID.NO.308.GI.54306075.T
 SEQ.ID.NO.309.GI.56202321.T
 SEQ.ID.NO.310.CLONE.1792902.T
 SEQ.ID.NO.311.CLONE.1727738.T

PQPEALVVNG
 PQPEALVANG
 ---T---LKDA
 PQPEALVVNG
 PQPEALVING
 ---S---LKDV
 PQPEALVING
 PQPEALVING

-GSK
 -GSK
 -PAA
 -GSK
 -GSK
 -PVS
 -GSK
 -GSK

193
 200
 189
 193
 199
 188
 199
 200

**NUCLEOTIDE SEQUENCES AND
CORRESPONDING POLYPEPTIDES
CONFERRING MODULATED GROWTH
RATE AND BIOMASS IN PLANTS GROWN
IN SALINE CONDITIONS**

This application is a Divisional of co-pending application Ser. No. 16/554,199, filed Aug. 28, 2019, which is a Divisional of co-pending application Ser. No. 16/275,537, filed Feb. 14, 2019, patented as 10,428,346, which is a Divisional of co-pending application Ser. No. 15/487,287, filed Apr. 13, 2017, patented as U.S. Pat. No. 10,233,460 which is a Divisional of application Ser. No. 13/663,204, filed Oct. 29, 2012, patented as U.S. Pat. No. 9,637,756, which is a Divisional of application Ser. No. 12/282,342 filed on Nov. 17, 2008, patented as U.S. Pat. No. 8,324,454, and for which priority is claimed under 35 U.S.C. § 120. Application Ser. No. 12/282,342 is a National Phase under 35 U.S.C. § 371 of PCT International Application No. PCT/US2007/006544, which has the International filing date of Mar. 14, 2007, and which claims priority under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 60/782,735, filed Mar. 14, 2006, the entire contents of each of which are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to isolated nucleic acid molecules and their corresponding encoded polypeptides able to enhance plant growth under saline conditions. The present invention further relates to using the nucleic acid molecules and polypeptides to make transgenic plants, plant cells, plant materials or seeds of a plant having improved growth rate, vegetative growth, seedling vigor and/or biomass under saline conditions as compared to wild-type plants grown under similar conditions.

BACKGROUND OF THE INVENTION

Plants specifically improved for agriculture, horticulture, biomass conversion, and other industries (e.g. paper industry, plants as production factories for proteins or other compounds) can be obtained using molecular technologies. As an example, great agronomic value can result from enhancing plant growth in saline conditions.

A wide variety agriculturally important plant species demonstrate significant sensitivity to saline water and/or soil. Upon salt concentration exceeding a relatively low threshold, many plants suffer from stunted growth, necrosis, and death that results in an overall stunted appearance and reduced yields of plant material, seeds, fruit and other valuable products. Physiologically, plants challenged with salinity experience disruption in ion and water homeostasis, inhibition of metabolism, and damage to cellular membranes that result in developmental arrest and cell death (Huh et al. (2002) *Plant J*, 29(5):649-59).

In many of the world's most productive agricultural regions, agricultural activities themselves lead to increased water and soil salinity, which threatens their sustained productivity. One example is crop irrigation in arid regions that have abundant sunlight. After irrigation water is applied to cropland, it is removed by the processes of evaporation and evapotranspiration. While these processes remove water from the soil, they leave behind dissolved salts carried in irrigation water. Consequently, soil and groundwater salt concentrations build over time, rendering the land and shallow groundwater saline and thus damaging to crops.

In addition to human activities, natural geological processes have created vast tracts of saline land that would be highly productive if not saline. In total, approximately 20% of the irrigated lands in are negatively affected by salinity.

(Yamaguchi and Blumwald, 2005, *Trends in Plant Science*, 10: 615-620). For these and other reasons, it is of great interest and importance to identify genes that confer improved salt tolerance characteristics to thereby enable one to create transgenic plants (such as crop plants) with enhanced growth and/or productivity characteristics in saline conditions.

The availability and sustainability of a stream of food and feed for people and domesticated animals has been a high priority throughout the history of human civilization and lies at the origin of agriculture. Specialists and researchers in the fields of agronomy science, agriculture, crop science, horticulture, and forest science are even today constantly striving to find and produce plants with an increased growth potential to feed an increasing world population and to guarantee a supply of reproducible raw materials. The robust level of research in these fields of science indicates the level of importance leaders in every geographic environment and climate around the world place on providing sustainable sources of food, feed and energy.

Manipulation of crop performance has been accomplished conventionally for centuries through selection and plant breeding. The breeding process is, however, both time-consuming and labor-intensive. Furthermore, appropriate breeding programs must be specially designed for each relevant plant species.

On the other hand, great progress has been made in using molecular genetic approaches to manipulate plants to provide better crops. Through the introduction and expression of recombinant nucleic acid molecules in plants, researchers are now poised to provide the community with plant species tailored to grow more efficiently and yield more product despite suboptimal geographic and/or climatic environments. These new approaches have the additional advantage of not being limited to one plant species, but instead being applicable to multiple different plant species (Zhang et al. (2004) *Plant Physiol.* 135:615; Zhang et al. (2001) *Proc. Natl. Acad. Sci. USA* 98:12832).

Despite this progress, today there continues to be a great need for generally applicable processes that improve forest or agricultural plant growth to suit particular needs depending on specific environmental conditions. To this end, the present invention is directed to advantageously manipulating plant tolerance to salinity in order to maximize the benefits of various crops depending on the benefit sought, and is characterized by expression of recombinant DNA molecules in plants. These molecules may be from the plant itself, and simply expressed at a higher or lower level, or the molecules may be from different plant species.

SUMMARY OF THE INVENTION

The present invention, therefore, relates to isolated nucleic acid molecules and polypeptides and their use in making transgenic plants, plant cells, plant materials or seeds of plants having improved growth characteristics in saline conditions compared to wild-type plants under similar or identical conditions.

The present invention also relates to processes for increasing the growth potential of plants challenged with saline conditions due to salt tolerance derived from recombinant nucleic acid molecules and polypeptides. The phrase "increasing growth potential" refers to continued growth in saline conditions, better yield after exposure to saline conditions and/or increased vigor in saline conditions.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 Amino acid sequence alignment of homologues of Ceres clone 8686 (SEQ ID NO: 80). Conserved regions are enclosed in a box.

FIG. 2. Amino acid sequence alignment of homologues of Ceres clone 375578 (SEQ ID NO: 252). Conserved regions are enclosed in a box.

FIG. 3 Amino acid sequence alignment of homologues of Ceres clone 105319 (SEQ ID NO: 106). Conserved regions are enclosed in a box.

FIG. 4 Amino acid sequence alignment of homologues of Ceres clone 29658 (SEQ ID NO: 123). Conserved regions are enclosed in a box.

FIG. 5 Amino acid sequence alignment of homologues of Ceres clone 2767 (SEQ ID NO: 132). Conserved regions are enclosed in a box.

FIG. 6 Amino acid sequence alignment of homologues of Ceres clone 16403 (SEQ ID NO: 146). Conserved regions are enclosed in a box.

FIG. 7 Amino acid sequence alignment of homologues of Ceres clone 3964 (SEQ ID NO: 154). Conserved regions are enclosed in a box.

FIG. 8 Amino acid sequence alignment of homologues of Ceres clone 965405 (SEQ ID NO: 172). Conserved regions are enclosed in a box.

FIG. 9 Amino acid sequence alignment of a conserved region of Ceres clones 375578 (SEQ ID NO: 306) and 335348 (SEQ ID NO: 304) and homologues. Conserved regions are enclosed in a box.

DETAILED DESCRIPTION OF THE INVENTION

1. The Invention

The present invention discloses novel isolated nucleic acid molecules, nucleic acid molecules that interfere with these nucleic acid molecules, nucleic acid molecules that hybridize to these nucleic acid molecules, and isolated nucleic acid molecules that encode the same protein due to the degeneracy of the DNA code. Additional embodiments of the present invention further include the polypeptides encoded by the isolated nucleic acid molecules of the present invention.

More particularly, the nucleic acid molecules of the present invention comprise: (a) a nucleotide sequence that encodes an amino acid sequence and that is at least 85% identical to any one of SEQ ID Nos. 80, 99, 106, 123, 132, 146, 154 and 172 respectively, (b) a nucleotide sequence that is complementary to any one of the nucleotide sequences according to (a), (c) a nucleotide sequence according to any one of SEQ ID NOS. 79, 98, 105, 122, 131, 145, 153 and 171, (d) a nucleotide sequence able to interfere with any one of the nucleotide sequences according to (a), (e) a nucleotide sequence able to form a hybridized nucleic acid duplex with the nucleic acid according to any one of paragraphs (a)-(d) at a temperature from about 5° C. to about 10° C. below a melting temperature of the hybridized nucleic acid duplex, (f) a nucleotide sequence encoding any one of amino acid sequences of SEQ ID NOS. 80, 99, 106, 123, 132, 146, 154 and 172, (g) a nucleotide sequence encoding any one of the amino acid sequences with an HMM bit score greater than 20 that fits an HMM based on the sequences aligned in any one of FIGS. 1-8, and (h) a nucleotide sequence encoding an amino acid sequence having a fragment that fits an HMM based on the sequences aligned in FIG. 9 and which has an HMM bit score greater than 400.

Additional embodiments of the present invention include those polypeptide and nucleic acid molecule sequences disclosed in SEQ ID NOS: 81-97, 100-104, 107-121, 124-130, 133-144, 147-152, 155-170, 173-252 and 269-315.

The present invention further embodies a vector comprising a first nucleic acid having a nucleotide sequence encoding a plant transcription and/or translation signal, and a second nucleic acid having a nucleotide sequence according

to the isolated nucleic acid molecules of the present invention. More particularly, the first and second nucleic acids may be operably linked. Even more particularly, the second nucleic acid may be endogenous to a first organism, and any other nucleic acid in the vector may be endogenous to a second organism. Most particularly, the first and second organisms may be different species.

In a further embodiment of the present invention, a host cell may comprise an isolated nucleic acid molecule according to the present invention. More particularly, the isolated nucleic acid molecule of the present invention found in the host cell of the present invention may be endogenous to a first organism and may be flanked by nucleotide sequences endogenous to a second organism. Further, the first and second organisms may be different species. Even more particularly, the host cell of the present invention may comprise a vector according to the present invention, which itself comprises nucleic acid molecules according to those of the present invention.

In another embodiment of the present invention, the isolated polypeptides of the present invention may additionally comprise amino acid sequences that are at least 85% identical to any one of SEQ ID Nos. 80, 99, 106, 123, 132, 146, 154 and 172.

Other embodiments of the present invention include methods of introducing an isolated nucleic acid of the present invention into a host cell. More particularly, an isolated nucleic acid molecule of the present invention may be contacted to a host cell under conditions allowing transport of the isolated nucleic acid into the host cell. Even more particularly, a vector as described in a previous embodiment of the present invention may be introduced into a host cell by the same method.

Methods of detection are also available as embodiments of the present invention. Particularly, methods for detecting a nucleic acid molecule according to the present invention in a sample. More particularly, the isolated nucleic acid molecule according to the present invention may be contacted with a sample under conditions that permit a comparison of the nucleotide sequence of the isolated nucleic acid molecule with a nucleotide sequence of nucleic acid in the sample. The results of such an analysis may then be considered to determine whether the isolated nucleic acid molecule of the present invention is detectable and therefore present within the sample.

A further embodiment of the present invention comprises a plant, plant cell, plant material or seeds of plants comprising an isolated nucleic acid molecule and/or vector of the present invention. More particularly, the isolated nucleic acid molecule of the present invention may be exogenous to the plant, plant cell, plant material or seed of a plant.

A further embodiment of the present invention includes a plant regenerated from a plant cell or seed according to the present invention. More particularly, the plant, or plants derived from the plant, plant cell, plant material or seeds of a plant of the present invention preferably has increased size (in whole or in part), increased vegetative growth and/or increased biomass (sometimes hereinafter collectively referred to as increased biomass) in saline conditions, as compared to a wild-type plant cultivated under identical conditions. Furthermore, the transgenic plant may comprise a first isolated nucleic acid molecule of the present invention, which encodes a protein involved in improving growth and phenotype characteristics in saline conditions, and a second isolated nucleic acid molecule which encodes a promoter capable of driving expression in plants, wherein the growth and phenotype improving component and the promoter are operably linked. More preferably, the first isolated nucleic acid may be mis-expressed in the transgenic plant of the present invention, and the transgenic plant exhibits improved characteristics as compared to a progenitor plant devoid of the polynucleotide, when the transgenic

plant and the progenitor plant are cultivated under identical, saline conditions. In another embodiment of the present invention the improved growth and phenotype characteristics may be due to the inactivation of a particular sequence, using for example an interfering RNA.

A further embodiment consists of a plant, plant cell, plant material or seed of a plant according to the present invention which comprises an isolated nucleic acid molecule of the present invention, wherein the plant, or plants derived from the plant, plant cell, plant material or seed of a plant, has the improved growth and phenotype characteristics in saline conditions as compared to a wild-type plant cultivated under identical conditions.

The polynucleotide conferring increased biomass or vigor in saline conditions may be mis-expressed in the transgenic plant of the present invention, and the transgenic plant exhibits an increased biomass or vigor as compared to a progenitor plant devoid of the polynucleotide, when the transgenic plant and the progenitor plant are cultivated under identical saline conditions. In another embodiment of the present invention increased biomass or vigor phenotype may be due to the inactivation of a particular sequence, using for example an interfering RNA.

Another embodiment consists of a plant, plant cell, plant material or seed of a plant according to the present invention which comprises an isolated nucleic acid molecule of the present invention, wherein the plant, or plants derived from the plant, plant cell, plant material or seed of a plant, has increased biomass or vigor in saline conditions as compared to a wild-type plant cultivated under identical conditions.

Another embodiment of the present invention includes methods of enhancing biomass or vigor in plants challenged with saline conditions. More particularly, these methods comprise transforming a plant with an isolated nucleic acid molecule according to the present invention. Preferably, the method is a method of enhancing biomass or vigor in the transgenic plant, whereby the plant is transformed with a nucleic acid molecule encoding the polypeptide of the present invention.

Polypeptides of the present invention include sequences belonging to the consensus sequence families shown in FIGS. 1-9 as delineated by Hidden Markov Models (HMMs).

2. Definitions

The following terms are utilized throughout this application:

Functionally Comparable Proteins or Functional Homologs: This phrase describes a set of proteins that perform similar functions within an organism. By definition, perturbation of an individual protein within that set (through misexpression or mutation, for example) is expected to confer a similar phenotype as compared to perturbation of any other individual protein. Such proteins typically share sequence similarity resulting in similar biochemical activity. Within this definition, homologs, orthologs and paralogs are considered to be functionally comparable.

Functionally comparable proteins will give rise to the same characteristic to a similar, but not necessarily the same, degree. Typically, comparable proteins give the same characteristics where the quantitative measurement due to one of the comparables is at least 20% of the other; more typically, between 30 to 40%; even more typically, between 50-60%; even more typically between 70 to 80%; even more typically between 90 to 100% of the other.

Heterologous sequences: "Heterologous sequences" are those that are not operatively linked or are not contiguous to each other in nature. For example, a promoter from corn is considered heterologous to an *Arabidopsis* coding region sequence. Also, a promoter from a gene encoding a growth

factor from corn is considered heterologous to a sequence encoding the corn receptor for the growth factor. Regulatory element sequences, such as UTRs or 3' end termination sequences that do not originate in nature from the same gene as the coding sequence, are considered heterologous to said coding sequence. Elements operatively linked in nature and contiguous to each other are not heterologous to each other. On the other hand, these same elements remain operatively linked but become heterologous if other filler sequence is placed between them. Thus, the promoter and coding sequences of a corn gene expressing an amino acid transporter are not heterologous to each other, but the promoter and coding sequence of a corn gene operatively linked in a novel manner are heterologous.

Hidden Markov Model (HMM): HMM is a statistical description of a sequence family's consensus. The model is indicative of similarity of a polypeptide sequence to a group of structurally and functionally related polypeptides (Durbin, R., Eddy, S. R., Krogh, A. & Mitchison, G. J. *Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids* Cambridge University Press, Cambridge UK, 1998).

HMM based on specified sequences: An HMM profile based on specified sequences is the output model generated by the program HMMER 2.3.2 (released Oct. 3, 2003 under a GNU general public license, and available from various sources, such as the HMMER website on the internet) configured with default parameters, the model being built by the program using as input the specified sequences. The program outputs the model as a text file.

HMM bit score: An HMM bit score is a probabilistic indication of confidence that a sequence fits the model. The bit score reflects whether the sequence is a better fit to an HMM of interest than to a null model of nonhomologous sequences. A significant HMM bit score is greater than zero, but is typically greater than 20. The HMM bit score of a polypeptide sequence fitted to an HMM profile can be determined by fitting the polypeptide to the HMM with program HMMER 2.3.2 configured for global alignments.

Misexpression: The term "misexpression" refers to an increase or a decrease in the transcription of a coding region into a complementary RNA sequence as compared to the wild-type. This term also encompasses expression and/or translation of a gene or coding region or inhibition of such transcription and/or translation for a different time period as compared to the wild-type and/or from a non-natural location within the plant genome, including a gene or coding region from a different plant species or from a non-plant organism.

Percentage of sequence identity: As used herein, the term "percent sequence identity" refers to the degree of identity between any given query sequence and a subject sequence. A subject sequence typically has a length that is from about 80 percent to 250 percent of the length of the query sequence, e.g., 82, 85, 87, 89, 90, 93, 95, 97, 99, 100, 105, 110, 115, or 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, or 250 percent of the length of the query sequence. A query nucleic acid or amino acid sequence is aligned to one or more subject nucleic acid or amino acid sequences using the computer program ClustalW (version 1.83, default parameters), which allows alignments of nucleic acid or protein sequences to be carried out across their entire length (global alignment). Chenna et al. (2003) *Nucleic Acids Res.* 31(13):3497-500.

ClustalW calculates the best match between a query and one or more subject sequences, and aligns them so that identities, similarities and differences can be determined. Gaps of one or more residues can be inserted into a query sequence, a subject sequence, or both, to maximize sequence alignments. For fast pairwise alignment of nucleic acid sequences, the following default parameters are used: word size: 2; window size: 4; scoring method: percentage; number

of top diagonals: 4; and gap penalty: 5. For an alignment of multiple nucleic acid sequences, the following parameters are used: gap opening penalty: 10.0; gap extension penalty: 5.0; and weight transitions: yes. For fast pairwise alignment of protein sequences, the following parameters are used: word size: 1; window size: 5; scoring method: percentage; number of top diagonals: 5; gap penalty: 3. For multiple alignment of protein sequences, the following parameters are used: weight matrix: blosum; gap opening penalty: 10.0; gap extension penalty: 0.05; hydrophilic gaps: on; hydrophilic residues: Gly, Pro, Ser, Asn, Asp, Gln, Glu, Arg, and Lys; residue-specific gap penalties: on. The output is a sequence alignment that reflects the relationship between sequences. ClustalW can be run, for example, at the Baylor College of Medicine Search Launcher website and at the European Bioinformatics Institute website on the World Wide Web.

To determine a percent identity for polypeptide or nucleic acid sequences between a query and a subject sequence, the sequences are aligned using Clustal W and the number of identical matches in the alignment is divided by the query length, and the result is multiplied by 100. The output is the percent identity of the subject sequence with respect to the query sequence. It is noted that the percent identity value can be rounded to the nearest tenth. For example, 78.11, 78.12, 78.13, and 78.14 are rounded down to 78.1, while 78.15, 78.16, 78.17, 78.18, and 78.19 are rounded up to 78.2.

Photosynthetic efficiency: photosynthetic efficiency, or electron transport via photosystem II, is estimated by the relationship between Fm, the maximum fluorescence signal and the variable fluorescence, Fv. Here, a reduction in the optimum quantum yield (Fv/Fm) indicates stress and can be used to monitor the performance of transgenic plants compared to non-transgenic plants under salt stress conditions.

Regulatory Regions: The term "regulatory region" refers to nucleotide sequences that, when operably linked to a sequence, influence transcription initiation or translation initiation or transcription termination of said sequence and the rate of said processes, and/or stability and/or mobility of a transcription or translation product. As used herein, the term "operably linked" refers to positioning of a regulatory region and said sequence to enable said influence. Regulatory regions include, without limitation, promoter sequences, enhancer sequences, response elements, protein recognition sites, inducible elements, protein binding sequences, 5' and 3' untranslated regions (UTRs), transcriptional start sites, termination sequences, polyadenylation sequences, and introns. Regulatory regions can be classified in two categories, promoters and other regulatory regions.

Salt tolerance: Plant species vary in their capacity to tolerate salinity. "Salinity" can be defined as the set of environmental conditions under which a plant will begin to suffer the effects of elevated salt concentration, such as ion imbalance, decreased stomatal conductance, decreased photosynthesis, decreased growth rate, increased cell death, loss of turgor (wilting), or ovule abortion. For these reasons, plants experiencing salinity stress typically exhibit a significant reduction in biomass and/or yield.

Elevated salinity may be caused by natural, geological processes and by human activities, such as irrigation. Since plant species vary in their capacity to tolerate water deficit, the precise environmental salt conditions that cause stress cannot be generalized. However, under saline conditions, salt tolerant plants produce higher biomass, yield and survivorship than plants that are not salt tolerant. Differences in physical appearance, recovery and yield can be quantified and statistically analyzed using well known measurement and analysis methods.

Seedling area: The total leaf area of a young plant about 2 weeks old.

Seedling vigor: As used herein, "seedling vigor" refers to the plant characteristic whereby the plant emerges from soil

faster, has an increased germination rate (i.e., germinates faster), has faster and larger seedling growth and/or germinates faster under salt conditions as compared to the wild-type or control under similar conditions. Seedling vigor has often been defined to comprise the seed properties that determine "the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions".

Stringency: "Stringency," as used herein is a function of nucleic acid molecule probe length, nucleic acid molecule probe composition (G+C content), salt concentration, organic solvent concentration and temperature of hybridization and/or wash conditions. Stringency is typically measured by the parameter T_m , which is the temperature at which 50% of the complementary nucleic acid molecules in the hybridization assay are hybridized, in terms of a temperature differential from T_m . High stringency conditions are those providing a condition of $T_m-5^\circ\text{C}$. to $T_m-10^\circ\text{C}$. Medium or moderate stringency conditions are those providing $T_m-20^\circ\text{C}$. to $T_m-29^\circ\text{C}$. Low stringency conditions are those providing a condition of $T_m-40^\circ\text{C}$. to $T_m-48^\circ\text{C}$. The relationship between hybridization conditions and T_m (in $^\circ\text{C}$.) is expressed in the mathematical equation:

$$T_m = 81.5 - 16.6(\log_{10}[\text{Na}^+]) + 0.41(\% \text{G+C}) - (600/N) \quad (\text{I})$$

where N is the number of nucleotides of the nucleic acid molecule probe. This equation works well for probes 14 to 70 nucleotides in length that are identical to the target sequence. The equation below, for T_m of DNA-DNA hybrids, is useful for probes having lengths in the range of 50 to greater than 500 nucleotides, and for conditions that include an organic solvent (formamide):

$$T_m = 81.5 + 16.6 \log \left\{ \frac{[\text{Na}^+]}{(1 + 0.7[\text{Na}^+])} + 0.41(\% \text{G+C}) - 500/L \right\} + 0.63(\% \text{formamide}) \quad (\text{II})$$

where L represents the number of nucleotides in the probe in the hybrid (Bonner et al. (1973) *J. Mol. Biol.* 81:123). The T_m of Equation II is affected by the nature of the hybrid: for DNA-RNA hybrids, T_m is 10-15 $^\circ\text{C}$. higher than calculated; for RNA-RNA hybrids, T_m is 20-25 $^\circ\text{C}$. higher. Because the T_m decreases about 1 $^\circ\text{C}$. for each 1% decrease in homology when a long probe is used (Frischauf et al. (1983) *J. Mol Biol.* 170: 827-842), stringency conditions can be adjusted to favor detection of identical genes or related family members.

Equation II is derived assuming the reaction is at equilibrium. Therefore, hybridizations according to the present invention are most preferably performed under conditions of probe excess and allowing sufficient time to achieve equilibrium. The time required to reach equilibrium can be shortened by using a hybridization buffer that includes a hybridization accelerator such as dextran sulfate or another high volume polymer.

Stringency can be controlled during the hybridization reaction, or after hybridization has occurred, by altering the salt and temperature conditions of the wash solutions. The formulas shown above are equally valid when used to compute the stringency of a wash solution. Preferred wash solution stringencies lie within the ranges stated above; high stringency is 5-8 $^\circ\text{C}$. below T_m , medium or moderate stringency is 26-29 $^\circ\text{C}$. below T_m and low stringency is 45-48 $^\circ\text{C}$. below T_m .

For example, the hybridization step may be performed in aqueous hybridization solution at a temperature between 63 $^\circ\text{C}$. and 70 $^\circ\text{C}$., more preferably at a temperature between 65 $^\circ\text{C}$. and 68 $^\circ\text{C}$. and most preferably at a temperature of 65 $^\circ\text{C}$. Alternatively, the high stringency hybridization step may be performed in formamide hybridization solution at a temperature between 40 $^\circ\text{C}$. and 46 $^\circ\text{C}$., at a temperature between 41 $^\circ\text{C}$. and 44 $^\circ\text{C}$. and most preferably at a temperature of 42 $^\circ\text{C}$.

A wash step follows hybridization, and an initial wash is performed with wash solution 1 at 25 $^\circ\text{C}$. or 37 $^\circ\text{C}$. Follow-

ing the initial wash, additional washes are performed with wash solution 1 at a temperature between 63° C. and 70° C., more preferably at a temperature between 65° C. and 68° C. and most preferably at a temperature of 65° C. The number of additional wash steps can be 1, 2, 3, 4, 5 or more. The time of both the initial and additional wash steps may be 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, 30 minutes, 45 minutes, 1 hour, 1.5 hours, 2 hours or more.

Set forth below are the composition of the hybridization and wash solutions and their components. A person of ordinary skill in the art will recognize that these solutions are typical and exemplary of high stringency hybridization solutions.

Aqueous Hybridization Solution: 6×SSC or 6×SSPE

0.05% Blotto or 5×Denhardt's Reagent
100 µg/ml denatured salmon sperm DNA
0.05% SDS

Formamide Hybridization Solution: 50% Formamide

6×SSC or 6×SSPE
0.05% Blotto or 5×Denhardt's Reagent
100 µg/ml denatured salmon sperm DNA
0.05% SDS

Wash Solution 1: 2×SSC or SSPE

0.1% SDS

Wash Solution 2: 0.1×SSC or SSPE

0.5% SDS

20×SSC: 175.3 g NaCl

88.2 g Sodium Citrate
Bring to 800 ml with H₂O
Adjust to pH 7 with 10 n NaOH
Bring to 1 L with H₂O

20×SSPE: 175.3 g NaCl

27.6 g NaH₂PO₄
Bring to 800 ml with H₂O—H₂O
7.4 g EDTA
Adjust to pH 7.4 with 10 n NaOH
Bring to 1 L with H₂O

1× BLOTTO: 5% Non-fat dry milk

0.02% Sodium azide

50×Denhardt's Reagent: 5 g Ficoll

5 g Polyvinylpyrrolidone
5 g BSA

Adjust to 500 ml with H₂O

Superpool: As used in the context of the current invention, a "superpool" contains an equal amount of seed from 500 different events, representing 100 distinct exogenous nucleotide sequences. An event is a plant carrying a unique insertion of a distinct exogenous sequence which misexpresses that sequence. Transformation of a single polynucleotide sequence can result in multiple events because the sequence can insert in a different part of the genome with each transformation.

T₀: The term "T₀" refers to the whole plant, explant or callus tissue, inoculated with the transformation medium.

T₁: The term T₁ refers to either the progeny of the T₀ plant, in the case of whole-plant transformation, or the regenerated seedling in the case of explant or callous tissue transformation.

T₂: The term T₂ refers to the progeny of the T₁ plant. T₂ progeny are the result of self-fertilization or cross-pollination of a T₁ plant.

T₃: The term T₃ refers to second generation progeny of the plant that is the direct result of a transformation experiment. T₃ progeny are the result of self-fertilization or cross-pollination of a T₂ plant.

T₄: As used in the current application, the term T₄ refers to third generation progeny of the plant that is the direct result of a transformation experiment. T₄ progeny are the result of self-fertilization or cross pollination of a T₃ plant.

Transformation: Examples of means by which this can be accomplished are described below and include *Agrobacterium*-mediated transformation (of dicots (Needleman and

Wunsch (1970) *J. Mol. Biol.* 48:443; Pearson and Lipman (1988) *Proc. Natl. Acad. Sci. (USA)* 85: 2444), of monocots (Yamauchi et al. (1996) *Plant Mol Biol.* 30:321-9; Xu et al. (1995) *Plant Mol. Biol.* 27:237; Yamamoto et al. (1991) *Plant Cell* 3:371), and biolistic methods (P. Tijessen, "Hybridization with Nucleic Acid Probes" In Laboratory Techniques in Biochemistry and Molecular Biology, P. C. vand der Vliet, ed., c. 1993 by Elsevier, Amsterdam), electroporation, in planta techniques and the like. Such a plant containing the exogenous nucleic acid is referred to here as a T₀ for the primary transgenic plant and T₁ for the first generation.

3. Important Characteristics of the Polynucleotides and Polypeptides of the Invention

The nucleic acid molecules and polypeptides of the present invention are of interest because when the nucleic acid molecules are mis-expressed (i.e., when expressed at a non-natural location or in an increased or decreased amount relative to wild-type) they produce plants that exhibit improved salt tolerance as compared to wild-type plants, as evidenced by the results of various experiments disclosed below. In particular, plants transformed with at least one of the nucleic acid molecules and polypeptides of the present invention have increased salt growth index values as compared to wild-type plants. For example, plants transformed with the sequences of the present invention can exhibit increases in SGI values of at least 25%, at least 50%, at least 75%, at least 100%, at least 200%, at least 300%, at least 400%, or even at least 500%. This trait can be used to exploit or maximize plant products. For example, the nucleic acid molecules and polypeptides of the present invention are used to increase the expression of genes that cause the plant to have improved biomass, growth rate and/or seedling vigor in saline conditions.

Because the disclosed sequences and methods increase vegetative growth and growth rate in saline conditions, the disclosed methods can be used to enhance plant growth in plants irrigated with saline water and/or grown in saline soil. For example, plants of the invention show, under saline conditions, increased photosynthetic efficiency and increased seedling area as compared to a plant of the same species that is not genetically modified for substantial vegetative growth. Examples of increases in biomass production include increases of at least 5%, at least 20%, or even at least 50%, when compared to an amount of biomass production by a wild-type plant of the same species under identical conditions.

Seed or seedling vigor is an important characteristic that can greatly influence successful growth of a plant, such as crop plants. Adverse environmental conditions, such as saline conditions, can affect a plant growth cycle, germination of seeds and seedling vigor (i.e. vitality and strength under such conditions can differentiate between successful and failed crop growth). Seedling vigor has often been defined to comprise the seed properties that determine "the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions". Hence, it would be advantageous to develop plant seeds with increased vigor, particularly in elevated salinity.

For example, increased seedling vigor would be advantageous for cereal plants such as rice, maize, wheat, etc. production. For these crops, germination and growth can often be slowed or stopped by salination. Genes associated with increased seed vigor and/or salination tolerance have therefore been sought for producing improved crop varieties. (Walia et al. (2005) *Plant Physiology* 139:822-835).

4. The Polypeptides/Polynucleotides of the Invention

The polynucleotides of the present invention and the proteins expressed via translation of these polynucleotides

are set forth in the Sequence Listing, specifically SEQ ID NOs. 79-253 and 269-315. The Sequence Listing also consists of functionally comparable proteins. Polypeptides comprised of a sequence belonging to the consensus sequence families shown in FIGS. 1 to 9 as delineated by HMMs can be utilized for the purposes of the invention, namely to make transgenic plants with improved biomass, growth rate and/or seedling vigor in saline conditions.

5. Use of the Polypeptides to Make Transgenic Plants

To use the sequences of the present invention or a combination of them or parts and/or mutants and/or fusions and/or variants of them, recombinant DNA constructs are prepared that comprise the polynucleotide sequences of the invention inserted into a vector and that are suitable for transformation of plant cells. The construct can be made using standard recombinant DNA techniques (see, Sambrook et al., *Molecular Cloning: A Laboratory Manual*, Second Edition, Cold Spring Harbor Laboratory Press, 1989, New York.) and can be introduced into the plant species of interest by, for example, *Agrobacterium*-mediated transformation, or by other means of transformation, for example, as disclosed below.

The vector backbone may be any of those typically used in the field such as plasmids, viruses, artificial chromosomes, BACs, YACs, PACs and vectors such as, for instance, bacteria-yeast shuttle vectors, lambda phage vectors, T-DNA fusion vectors and plasmid vectors (see, Shizuya et al. (1992) *Proc. Natl. Acad. Sci. USA* 89: 8794-8797; Hamilton et al. (1996) *Proc. Natl. Acad. Sci. USA* 93: 9975-9979; Burke et al. (1987) *Science* 236:806-812; Sternberg N. et al. (1990) *Proc Natl Acad Sci USA*. 87:103-7; Bradshaw et al. (1995) *Nucl Acids Res* 23: 4850-4856; Frischauf et al. (1983) *J. Mol Biol* 170: 827-842; Huynh et al., Glover N M (ed) *DNA Cloning: A practical Approach*, Vol. 1 Oxford: IRL Press (1985); Walden et al. (1990) *Mol Cell Biol* 1: 175-194).

Typically, the construct comprises a vector containing a nucleic acid molecule of the present invention with any desired transcriptional and/or translational regulatory sequences such as, for example, promoters, UTRs, and 3' end termination sequences. Vectors may also include, for example, origins of replication, scaffold attachment regions (SARs), markers, homologous sequences, and introns. The vector may also comprise a marker gene that confers a selectable phenotype on plant cells. The marker may preferably encode a biocide resistance trait, particularly antibiotic resistance, such as resistance to, for example, kanamycin, bleomycin, or hygromycin, or herbicide resistance, such as resistance to, for example, glyphosate, chlorosulfuron or phosphinotricin.

It will be understood that more than one regulatory region may be present in a recombinant polynucleotide, e.g., introns, enhancers, upstream activation regions, transcription terminators, and inducible elements. Thus, more than one regulatory region can be operably linked to said sequence.

To "operably link" a promoter sequence to a sequence, the translation initiation site of the translational reading frame of said sequence is typically positioned between one and about fifty nucleotides downstream of the promoter. A promoter can, however, be positioned as much as about 5,000 nucleotides upstream of the translation initiation site, or about 2,000 nucleotides upstream of the transcription start site. A promoter typically comprises at least a core (basal) promoter. A promoter also may include at least one control element, such as an enhancer sequence, an upstream element or an upstream activation region (UAR). For example, a suitable enhancer is a cis-regulatory element (-212 to -154)

from the upstream region of the octopine synthase (ocs) gene. Fromm et al. (1989) *Plant Cell* 1:977-984.

Some suitable promoters initiate transcription only, or predominantly, in certain cell types. For example, a promoter that is active predominantly in a reproductive tissue (e.g., fruit, ovule, pollen, pistils, female gametophyte, egg cell, central cell, nucellus, suspensor, synergid cell, flowers, embryonic tissue, embryo sac, embryo, zygote, endosperm, integument, or seed coat) can be used. Thus, as used herein a cell type- or tissue-preferential promoter is one that drives expression preferentially in the target tissue, but may also lead to some expression in other cell types or tissues as well. Methods for identifying and characterizing promoter regions in plant genomic DNA include, for example, those described in the following references: Jordano, et al. (1989) *Plant Cell* 1:855-866; Bustos et al. (1989) *Plant Cell* 1:839-854; Green et al. (1988) *EMBO J.* 7: 4035-4044; Meier et al. (1991) *Plant Cell* 3: 309-316; and Zhang et al. (1996) *Plant Physiology* 110: 1069-1079.

Examples of various classes of promoters are described below. Some of the promoters indicated below are described in more detail in U.S. Patent Application Ser. Nos. 60/505,689; 60/518,075; 60/544,771; 60/558,869; 60/583,691; 60/619,181; 60/637,140; 10/950,321; 10/957,569; 11/058,689; 11/172,703; 11/208,308; and PCT/US05/23639. It will be appreciated that a promoter may meet criteria for one classification based on its activity in one plant species, and yet meet criteria for a different classification based on its activity in another plant species.

Other Regulatory Regions: A 5' untranslated region (UTR) can be included in nucleic acid constructs described herein. A 5' UTR is transcribed, but is not translated, and lies between the start site of the transcript and the translation initiation codon and may include the +1 nucleotide. A 3' UTR can be positioned between the translation termination codon and the end of the transcript. UTRs can have particular functions such as increasing mRNA stability or attenuating translation. Examples of 3' UTRs include, but are not limited to, polyadenylation signals and transcription termination sequences, e.g., a nopaline synthase termination sequence.

Various promoters can be used to drive expression of the polynucleotides of the present invention. Nucleotide sequences of such promoters are set forth in SEQ ID NOS: 1-78. Some of them can be broadly expressing promoters, others may be more tissue preferential.

A promoter can be said to be "broadly expressing" when it promotes transcription in many, but not necessarily all, plant tissues or plant cells. For example, a broadly expressing promoter can promote transcription of an operably linked sequence in one or more of the shoot, shoot tip (apex), and leaves, but weakly or not at all in tissues such as roots or stems. As another example, a broadly expressing promoter can promote transcription of an operably linked sequence in one or more of the stem, shoot, shoot tip (apex), and leaves, but can promote transcription weakly or not at all in tissues such as reproductive tissues of flowers and developing seeds. Non-limiting examples of broadly expressing promoters that can be included in the nucleic acid constructs provided herein include the p326 (SEQ ID NO: 76), YP0144 (SEQ ID NO: 55), YP0190 (SEQ ID NO: 59), p13879 (SEQ ID NO: 75), YP0050 (SEQ ID NO: 35), p32449 (SEQ ID NO: 77), 21876 (SEQ ID NO: 1), YP0158 (SEQ ID NO: 57), YP0214 (SEQ ID NO: 61), YP0380 (SEQ ID NO: 70), PT0848 (SEQ ID NO: 26), and PT0633 (SEQ ID NO: 7). Additional examples include the cauliflower mosaic virus (CaMV) 35S promoter, the mannopine synthase (MAS) promoter, the 1' or 2' promoters derived from T-DNA of *Agrobacterium tumefaciens*, the figwort mosaic virus 34S promoter, actin promoters such as the rice actin promoter, and ubiquitin promoters such as the maize ubiquitin-1

promoter. In some cases, the CaMV 35S promoter is excluded from the category of broadly expressing promoters.

Root-active promoters drive transcription in root tissue, e.g., root endodermis, root epidermis, or root vascular tissues. In some embodiments, root-active promoters are root-preferential promoters, i.e., drive transcription only or predominantly in root tissue. Root-preferential promoters include the YP0128 (SEQ ID NO: 52), YP0275 (SEQ ID NO: 63), PT0625 (SEQ ID NO: 6), PT0660 (SEQ ID NO: 9), PT0683 (SEQ ID NO: 14), and PT0758 (SEQ ID NO: 22). Other root-preferential promoters include the PT0613 (SEQ ID NO: 5), PT0672 (SEQ ID NO: 11), PT0688 (SEQ ID NO: 15), and PT0837 (SEQ ID NO: 24), which drive transcription primarily in root tissue and to a lesser extent in ovules and/or seeds. Other examples of root-preferential promoters include the root-specific subdomains of the CaMV 35S promoter (Lam et al. (1989) *Proc. Natl. Acad. Sci. USA* 86:7890-7894), root cell specific promoters reported by Conkling et al. (1990) *Plant Physiol.* 93:1203-1211 and the tobacco RD2 gene promoter.

In some embodiments, promoters that drive transcription in maturing endosperm can be useful. Transcription from a maturing endosperm promoter typically begins after fertilization and occurs primarily in endosperm tissue during seed development and is typically highest during the cellularization phase. Most suitable are promoters that are active predominantly in maturing endosperm, although promoters that are also active in other tissues can sometimes be used. Non-limiting examples of maturing endosperm promoters that can be included in the nucleic acid constructs provided herein include the napin promoter, the Arcelin-5 promoter, the phaseolin gene promoter (Bustos et al. (1989) *Plant Cell* 1(9):839-853), the soybean trypsin inhibitor promoter (Riggs et al. (1989) *Plant Cell* 1(6):609-621), the ACP promoter (Baerson et al. (1993) *Plant Mol Biol.* 22(2):255-267), the stearyl-ACP desaturase gene (Slocombe et al. (1994) *Plant Physiol* 104(4):167-176), the soybean α' subunit of β -conglycinin promoter (Chen et al. (1986) *Proc Natl Acad Sci USA* 83:8560-8564), the oleosin promoter (Hong et al. (1997) *Plant Mol Biol* 34(3):549-555), and zein promoters, such as the 15 kD zein promoter, the 16 kD zein promoter, 19 kD zein promoter, 22 kD zein promoter and 27 kD zein promoter. Also suitable are the Osgt-1 promoter from the rice glutelin-1 gene (Zheng et al. (1993) *Mol. Cell Biol.* 13:5829-5842), the beta-amylase gene promoter, and the barley hordein gene promoter. Other maturing endosperm promoters include the YP0092 (SEQ ID NO: 38), PT0676 (SEQ ID NO: 12), and PT0708 (SEQ ID NO: 17).

Promoters that drive transcription in ovary tissues such as the ovule wall and mesocarp can also be useful, e.g., a polygalacturonidase promoter, the banana TRX promoter, and the melon actin promoter. Other such promoters that drive gene expression preferentially in ovules are YP0007 (SEQ ID NO: 30), YP0111 (SEQ ID NO: 46), YP0092 (SEQ ID NO: 38), YP0103 (SEQ ID NO: 43), YP0028 (SEQ ID NO: 33), YP0121 (SEQ ID NO: 51), YP0008 (SEQ ID NO: 31), YP0039 (SEQ ID NO: 34), YP0115 (SEQ ID NO: 47), YP0119 (SEQ ID NO: 49), YP0120 (SEQ ID NO: 50) and YP0374 (SEQ ID NO: 68).

In some other embodiments of the present invention, embryo sac/early endosperm promoters can be used in order to drive transcription of the sequence of interest in polar nuclei and/or the central cell, or in precursors to polar nuclei, but not in egg cells or precursors to egg cells. Most suitable are promoters that drive expression only or predominantly in polar nuclei or precursors thereto and/or the central cell. A pattern of transcription that extends from polar nuclei into early endosperm development can also be found with embryo sac/early endosperm-preferential promoters, although transcription typically decreases significantly in

later endosperm development during and after the cellularization phase. Expression in the zygote or developing embryo typically is not present with embryo sac/early endosperm promoters.

Promoters that may be suitable include those derived from the following genes: *Arabidopsis* viviparous-1 (see, GenBank No. U93215); *Arabidopsis* atmycl (see Urao (1996) *Plant Mol. Biol.*, 32:571-57; Conceicao (1994) *Plant*, 5:493-505); *Arabidopsis* HE (GenBank No. AF129516); *Arabidopsis* MEA; *Arabidopsis* FIS2 (GenBank No. AF096096); and FIE 1.1 (U.S. Pat. No. 6,906,244). Other promoters that may be suitable include those derived from the following genes: maize MAC1 (see, Sheridan (1996) *Genetics*, 142:1009-1020); maize Cat3 (see, GenBank No. L05934; Abler (1993) *Plant Mol. Biol.*, 22:10131-1038). Other promoters include the following *Arabidopsis* promoters: YP0039 (SEQ ID NO: 34), YP0101 (SEQ ID NO: 41), YP0102 (SEQ ID NO: 42), YP0110 (SEQ ID NO: 45), YP0117 (SEQ ID NO: 48), YP0119 (SEQ ID NO: 49), YP0137 (SEQ ID NO: 53), DME, YP0285 (SEQ ID NO: 64), and YP0212 (SEQ ID NO: 60). Other promoters that may be useful include the following rice promoters: p530c10, pOsFIE2-2, pOsMEA, pOsYp102, and pOsYp285.

Promoters that preferentially drive transcription in zygotic cells following fertilization can provide embryo-preferential expression and may be useful for the present invention. Most suitable are promoters that preferentially drive transcription in early stage embryos prior to the heart stage, but expression in late stage and maturing embryos is also suitable. Embryo-preferential promoters include the barley lipid transfer protein (Ltp1) promoter (*Plant Cell Rep* (2001) 20:647-654, YP0097 (SEQ ID NO: 40), YP0107 (SEQ ID NO: 44), YP0088 (SEQ ID NO: 37), YP0143 (SEQ ID NO: 54), YP0156 (SEQ ID NO: 56), PT0650 (SEQ ID NO: 8), PT0695 (SEQ ID NO: 16), PT0723 (SEQ ID NO: 19), PT0838 (SEQ ID NO: 25), PT0879 (SEQ ID NO: 28) and PT0740 (SEQ ID NO: 20).

Promoters active in photosynthetic tissue in order to drive transcription in green tissues such as leaves and stems are of particular interest for the present invention. Most suitable are promoters that drive expression only or predominantly such tissues. Examples of such promoters include the ribulose-1,5-bisphosphate carboxylase (RbcS) promoters such as the RbcS promoter from eastern larch (*Larix laricina*), the pine cab6 promoter (Yamamoto et al. (1994) *Plant Cell Physiol.* 35:773-778), the Cab-1 gene promoter from wheat (Fejes et al. (1990) *Plant Mol. Biol.* 15:921-932), the CAB-1 promoter from spinach (Lubberstedt et al. (1994) *Plant Physiol.* 104:997-1006), the cab1R promoter from rice (Luan et al. (1992) *Plant Cell* 4:971-981), the pyruvate orthophosphate dikinase (PPDK) promoter from corn (Matsuoka et al. (1993) *Proc Natl Acad. Sci USA* 90:9586-9590), the tobacco Lhcb1*2 promoter (Cerdan et al. (1997) *Plant Mol. Biol.* 33:245-255), the *Arabidopsis thaliana* SUC2 sucrose-H⁺ symporter promoter (Truernit et al. (1995) *Planta* 196:564-570), and thylakoid membrane protein promoters from spinach (psaD, psaF, psaE, PC, FNR, atpC, atpD, cab, rbcS). Other promoters that drive transcription in stems, leafs and green tissue are PT0535 (SEQ ID NO: 3), PT0668 (SEQ ID NO: 2), PT0886 (SEQ ID NO: 29), PR0924 (SEQ ID NO: 265), YP0144 (SEQ ID NO: 55), YP0380 (SEQ ID NO: 70) and PT0585 (SEQ ID NO: 4).

In some other embodiments of the present invention, inducible promoters may be desired. Inducible promoters drive transcription in response to external stimuli such as chemical agents or environmental stimuli. For example, inducible promoters can confer transcription in response to hormones such as giberellic acid or ethylene, or in response to light or drought. Examples of drought inducible promoters are YP0380 (SEQ ID NO: 70), PT0848 (SEQ ID NO: 26), YP0381 (SEQ ID NO: 71), YP0337 (SEQ ID NO: 66), PT0633 (SEQ ID NO: 7), YP0374 (SEQ ID NO: 68),

PT0710 (SEQ ID NO: 18), YP0356 (SEQ ID NO: 67), YP0385 (SEQ ID NO: 73), YP0396 (SEQ ID NO: 74), YP0384 (SEQ ID NO: 72), PT0688 (SEQ ID NO: 15), YP0286 (SEQ ID NO: 65), YP0377 (SEQ ID NO: 69), and PD1367 (SEQ ID NO: 78). Examples of promoters induced by nitrogen are PT0863 (SEQ ID NO: 27), PT0829 (SEQ ID NO: 23), PT0665 (SEQ ID NO: 10) and PT0886 (SEQ ID NO: 29). An example of a promoter induced by salt is rd29A (Kasuga et al. (1999) *Nature Biotech* 17: 287-291).

Other Promoters: Other classes of promoters include, but are not limited to, leaf-preferential, stem/shoot-preferential, callus-preferential, guard cell-preferential, such as PT0678 (SEQ ID NO: 13), and senescence-preferential promoters. Promoters designated YP0086 (SEQ ID NO: 36), YP0188 (SEQ ID NO: 58), YP0263 (SEQ ID NO: 62), PT0758 (SEQ ID NO: 22), PT0743 (SEQ ID NO: 21), PT0829 (SEQ ID NO: 23), YP0119 (SEQ ID NO: 49), and YP0096 (SEQ ID NO: 39), as described in the above-referenced patent applications, may also be useful.

Alternatively, misexpression can be accomplished using a two component system, whereby the first component consists of a transgenic plant comprising a transcriptional activator operatively linked to a promoter and the second component consists of a transgenic plant that comprise a nucleic acid molecule of the invention operatively linked to the target-binding sequence/region of the transcriptional activator. The two transgenic plants are crossed and the nucleic acid molecule of the invention is expressed in the progeny of the plant. In another alternative embodiment of the present invention, the misexpression can be accomplished by having the sequences of the two component system transformed in one transgenic plant line.

Another alternative consists in inhibiting expression of a biomass or vigor-modulating polypeptide in a plant species of interest under saline conditions. The term "expression" refers to the process of converting genetic information encoded in a polynucleotide into RNA through transcription of the polynucleotide (i.e., via the enzymatic action of an RNA polymerase), and into protein through translation of mRNA. "Up-regulation" or "activation" refers to regulation that increases the production of expression products relative to basal or native states, while "down-regulation" or "repression" refers to regulation that decreases production relative to basal or native states.

A number of nucleic-acid based methods, including antisense RNA, ribozyme directed RNA cleavage, and interfering RNA (RNAi) can be used to inhibit protein expression in plants. Antisense technology is one well-known method. In this method, a nucleic acid segment from the endogenous gene is cloned and operably linked to a promoter so that the antisense strand of RNA is transcribed. The recombinant vector is then transformed into plants, as described above, and the antisense strand of RNA is produced. The nucleic acid segment need not be the entire sequence of the endogenous gene to be repressed, but typically will be substantially identical to at least a portion of the endogenous gene to be repressed. Generally, higher homology can be used to compensate for the use of a shorter sequence. Typically, a sequence of at least 30 nucleotides is used (e.g., at least 40, 50, 80, 100, 200, 500 nucleotides or more).

Thus, for example, an isolated nucleic acid provided herein can be an antisense nucleic acid to one of the aforementioned nucleic acids encoding a polypeptide modulates biomass under saline conditions. A nucleic acid that decreases the level of a transcription or translation product of a gene encoding a biomass-modulating polypeptide is transcribed into an antisense nucleic acid similar or identical to the sense coding sequence of the biomass- or growth rate-modulating polypeptide. Alternatively, the transcription product of an isolated nucleic acid can be similar or identical to the sense coding sequence of a biomass growth rate-

modulating polypeptide, but is an RNA that is unpolyadenylated, lacks a 5' cap structure, or contains an unsplicable intron.

In another method, a nucleic acid can be transcribed into a ribozyme, or catalytic RNA, that affects expression of an mRNA. (See, U.S. Pat. No. 6,423,885). Ribozymes can be designed to specifically pair with virtually any target RNA and cleave the phosphodiester backbone at a specific location, thereby functionally inactivating the target RNA. Heterologous nucleic acids can encode ribozymes designed to cleave particular mRNA transcripts, thus preventing expression of a polypeptide. Hammerhead ribozymes are useful for destroying particular mRNAs, although various ribozymes that cleave mRNA at site-specific recognition sequences can be used. Hammerhead ribozymes cleave mRNAs at locations dictated by flanking regions that form complementary base pairs with the target mRNA. The sole requirement is that the target RNA contains a 5'-UG-3' nucleotide sequence. The construction and production of hammerhead ribozymes is known in the art. See, for example, U.S. Pat. No. 5,254,678 and WO 02/46449 and references cited therein. Hammerhead ribozyme sequences can be embedded in a stable RNA such as a transfer RNA (tRNA) to increase cleavage efficiency in vivo. Perriman, et al. (1995) *Proc. Natl. Acad. Sci. USA*, 92(13):6175-6179; de Feyter and Gaudron, *Methods in Molecular Biology*, Vol. 74, Chapter 43, "Expressing Ribozymes in Plants", Edited by Turner, P. C, Humana Press Inc., Totowa, N.J. RNA endoribonucleases such as the one that occurs naturally in *Tetrahymena thermophila*, and which have been described extensively by Cech and collaborators can be useful. See, for example, U.S. Pat. No. 4,987,071.

Methods based on RNA interference (RNAi) can be used. RNA interference is a cellular mechanism to regulate the expression of genes and the replication of viruses. This mechanism is thought to be mediated by double-stranded small interfering RNA molecules. A cell responds to such a double-stranded RNA by destroying endogenous mRNA having the same sequence as the double-stranded RNA. Methods for designing and preparing interfering RNAs are known to those of skill in the art; see, e.g., WO 99/32619 and WO 01/75164. For example, a construct can be prepared that includes a sequence that is transcribed into an interfering RNA. Such an RNA can be one that can anneal to itself, e.g., a double stranded RNA having a stem-loop structure. One strand of the stem portion of a double stranded RNA comprises a sequence that is similar or identical to the sense coding sequence of the polypeptide of interest, and that is from about 10 nucleotides to about 2,500 nucleotides in length. The length of the sequence that is similar or identical to the sense coding sequence can be from 10 nucleotides to 500 nucleotides, from 15 nucleotides to 300 nucleotides, from 20 nucleotides to 100 nucleotides, or from 25 nucleotides to 100 nucleotides. The other strand of the stem portion of a double stranded RNA comprises an antisense sequence of the biomass-modulating polypeptide of interest, and can have a length that is shorter, the same as, or longer than the corresponding length of the sense sequence. The loop portion of a double stranded RNA can be from 10 nucleotides to 5,000 nucleotides, e.g., from 15 nucleotides to 1,000 nucleotides, from 20 nucleotides to 500 nucleotides, or from 25 nucleotides to 200 nucleotides. The loop portion of the RNA can include an intron. See, e.g., WO 99/53050.

Transcriptional silencing of the target gene can also be achieved via the promoter through expression of an RNAi construct. This results in the synthesis of double stranded RNA molecules of which the nucleotides sequence is identical to a part of the promoter region of the target gene.

Another alternative method for suppression of the target gene may be achieved through a methodology generally referred to as Virus Induced Gene Silencing or VIGS (Ratcliff et al (2001) *Plant J.* 25, 237-245). Here, effective and

specific gene silencing is achieved by infection of a plant with a plant virus carrying an insert which is homologous to the target gene. The advantage of the VIGS system is that there is no need to develop a plant transformation protocol for the plant species in which the target gene resides.

In all of these silencing methods, the silencing construct (antisense RNA, co-suppression, RNAi or hairpin construct or VIGs vector) preferably contains a DNA fragment that is identical to the target sequence (gene or promoter) that needs to be silenced. The percentage of identity may, however, range between 50-100%, preferably between 60-100%, more preferably between 70-100%, even more preferably between 80-100% and most preferably between 90-100%.

In some nucleic-acid based methods for inhibition of gene expression in plants, a suitable nucleic acid can be a nucleic acid analog. Nucleic acid analogs can be modified at the base moiety, sugar moiety, or phosphate backbone to improve, for example, stability, hybridization, or solubility of the nucleic acid. Modifications at the base moiety include deoxyuridine for deoxythymidine, and 5-methyl-2'-deoxycytidine and 5-bromo-2'-deoxycytidine for deoxycytidine. Modifications of the sugar moiety include modification of the 2' hydroxyl of the ribose sugar to form 2'-O-methyl or 2'-O-allyl sugars. The deoxyribose phosphate backbone can be modified to produce morpholino nucleic acids, in which each base moiety is linked to a six-membered morpholino ring, or peptide nucleic acids, in which the deoxyphosphate backbone is replaced by a pseudopeptide backbone and the four bases are retained. See, for example, Summerton and Weller, 1997, *Antisense Nucleic Acid Drug Dev.*, 7:187-195; Hyrup et al., 1996, *Bioorgan. Med. Chem.*, 4: 5-23. In addition, the deoxyphosphate backbone can be replaced with, for example, a phosphorothioate or phosphorodithioate backbone, a phosphoroamidite, or an alkyl phosphotriester backbone.

Transformation

Nucleic acid molecules of the present invention may be introduced into the genome or the cell of the appropriate host plant by a variety of techniques. These techniques, able to transform a wide variety of higher plant species, are well known and described in the technical and scientific literature (see, e.g., Weising et al. (1988) *Ann. Rev. Genet.*, 22:421 and Christou (1995) *Euphytica*, 85:13-27).

A variety of techniques known in the art are available for the introduction of DNA into a plant host cell. These techniques include transformation of plant cells by injection (Newell (2000) *Mol Biotech* 16:53-65), microinjection (Griesbach (1987) *Plant Sci.* 50:69-77), electroporation of DNA (Fromm et al. (1985) *Proc. Natl. Acad. Sci. USA* 82:5824), PEG (Paszowski et al. (1984) *EMBO J.* 3:2717), use of biolistics (Klein et al. (1987) *Nature* 327:773), fusion of cells or protoplasts (Willmitzer, L. (1993) *Transgenic Plants*. In: *Iotechnology, A Multi-Volume Comprehensive treatise* (H. J. Rehm, G. Reed, A. Püler, P. Stadler, eds., Vol. 2, 627-659, VCH Weinheim-New York-Basel-Cambridge), and via T-DNA using *Agrobacterium tumefaciens* (*Crit. Rev. Plant. Sci.* 4:1-46; Fromm et al. (1990) *Biotechnology* 8:833-844) or *Agrobacterium rhizogenes* (Cho et al. (2000) *Planta* 210:195-204) or other bacterial hosts (Broothaerts et al. (2005) *Nature* 433:629-633), for example.

In addition, a number of non-stable transformation methods that are well known to those skilled in the art may be desirable for the present invention. Such methods include, but are not limited to, transient expression (Lincoln et al. (1998) *Plant Mol. Biol. Rep.* 16:1-4) and viral transfection (Lacomme et al. (2001), "Genetically Engineered Viruses" (C. J. A. Ring and E. D. Blair, Eds). Pp. 59-99, BIOS Scientific Publishers, Ltd. Oxford, UK).

Seeds are obtained from the transformed plants and used for testing stability and inheritance. Generally, two or more generations are cultivated to ensure that the phenotypic feature is stably maintained and transmitted.

A person of ordinary skill in the art recognizes that after the expression cassette is stably incorporated in transgenic plants and confirmed to be operable, it can be introduced into other plants by sexual crossing. Any of a number of standard breeding techniques can be used, depending upon the species to be crossed.

In aspects related to making transgenic plants, a typical step involves selection or screening of transformed plants, e.g., for the presence of a functional vector as evidenced by expression of a selectable marker. Selection or screening can be carried out among a population of recipient cells to identify transformants using selectable marker genes such as herbicide resistance genes. Physical and biochemical methods can be used to identify transformants. These include Southern analysis or PCR amplification for detection of a polynucleotide; Northern blots, S1 RNase protection, primer-extension, or RT-PCR amplification for detecting RNA transcripts; enzymatic assays for detecting enzyme or ribozyme activity of polypeptides and polynucleotides; and protein gel electrophoresis, Western blots, immunoprecipitation, and enzyme-linked immunoassays to detect polypeptides. Other techniques such as in situ hybridization, enzyme staining, and immunostaining also can be used to detect the presence or expression of polypeptides and/or polynucleotides. Methods for performing all of the referenced techniques are known.

A population of transgenic plants can be screened and/or selected for those members of the population that have a desired trait or phenotype conferred by expression of the transgene. For example, a population of progeny of a single transformation event can be screened for those plants having a desired level of expression of a heterologous salt tolerance polypeptide or nucleic acid. As an alternative, a population of plants comprising independent transformation events can be screened for those plants having a desired trait, such as salt tolerance. Selection and/or screening can be carried out over one or more generations, which can be useful to identify those plants that have a statistically significant difference in a protein level as compared to a corresponding level in a control plant. Selection and/or screening can also be carried out in more than one geographic location. In some cases, transgenic plants can be grown and selected under conditions which induce a desired phenotype or are otherwise necessary to produce a desired phenotype in a transgenic plant. In addition, selection and/or screening can be carried out during a particular developmental stage in which the phenotype is expected to be exhibited by the plant. Selection and/or screening can be carried out to choose those transgenic plants having a statistically significant difference in salt tolerance relative to a control plant that lacks the transgene. Selected or screened transgenic plants have an altered phenotype as compared to a corresponding control plant, as described elsewhere in this specification.

The nucleic acid molecules of the present invention may be used to confer the trait of improved tolerance to saline conditions. The invention has utility in improving important agronomic characteristics of crop plants, for example enabling plants to be productively cultivated in saline conditions. As noted above, transgenic plants that exhibit over-expression of the polynucleotides of the invention grow well under high salt conditions.

The nucleic acid molecules of the present invention encode appropriate proteins from any organism, but are preferably found in plants, fungi, bacteria or animals.

Transgenic Plant Phenotypes

Information that the polypeptides disclosed herein can modulate salt tolerance is useful in breeding of crop plants. Based on the effect of the disclosed polypeptides on salt tolerance, one can search for and identify polymorphisms linked to genetic loci for such polypeptides. Polymorphisms that can be identified include simple sequence repeats

(SSRs), amplified fragment length polymorphisms (AFLPs) and restriction fragment length polymorphisms (RFLPs).

If a polymorphism is identified, its presence and frequency in populations is analyzed to determine if it is statistically significantly correlated to an increase in salt tolerance. Those polymorphisms that are correlated with an increase in salt tolerance can be incorporated into a marker assisted breeding program to facilitate the development of lines that have a desired increase in salt tolerance. Typically, a polymorphism identified in such a manner is used with polymorphisms at other loci that are also correlated with a desired increase in salt tolerance or other desired trait.

The methods according to the present invention can be applied to any plant, preferably higher plants, pertaining to the classes of Angiospermae and Gymnospermae. Plants of the subclasses of the Dicotyledonae and the Monocotyledonae are particularly suitable. Dicotyledonous plants belonging to the orders of the Magnoliales, Illiciales, Laurales, Piperales, Aristochiales, Nymphaeales, Ranunculales, Papaverales, Sarraceniaceae, Trochodendrales, Hamamelidales, Eucomiales, Leitneriales, Myricales, Fagales, Casuarinales, Caryophyllales, Batales, Polygonales, Plumbaginales, Dilleniales, Theales, Malvales, Urticales, Lecythidales, Violales, Salicales, Capparales, Ericales, Diapensales, Ebenales, Primulales, Rosales, Fabales, Podostemales, Haloragales, Myrtales, Cornales, Proteales, Santales, Rafflesiales, Celastrales, Euphorbiales, Rhamnales, Sapindales, Juglandales, Geraniales, Polygalales, Umbellales, Gentianales, Polemoniales, Lamiales, Plantaginales, Scrophulariales, Campanulales, Rubiales, Dipsacales, and Asterales, for example, are also suitable. Monocotyledonous plants belonging to the orders of the Alismatales, Hydrocharitales, Najadales, Triuridales, Commelinales, Eriocaulales, Restionales, Poales, Juncales, Cyperales, Typhales, Bromeliales, Zingiberales, Arecales, Cyclanthales, Pandanales, Arales, Lilliales, and Orchidales also may be useful in embodiments of the present invention. Further examples include, but are not limited to, plants belonging to the class of the Gymnospermae are Pinales, Ginkgoales, Cycadales and Gnetales.

The methods of the present invention are preferably used in plants that are important or interesting for agriculture, horticulture, biomass for bioconversion and/or forestry. Non-limiting examples include, for instance, tobacco, oil-seed rape, sugar beet, potatoes, tomatoes, cucumbers, peppers, beans, peas, citrus fruits, avocados, peaches, apples, pears, berries, plums, melons, eggplants, cotton, soybean, sunflowers, roses, poinsettia, *petunia*, guayule, cabbages, spinach, alfalfa, artichokes, sugarcane, *mimosa*, *Servicea lespedera*, corn, wheat, rice, rye, barley, sorghum and grasses such as switch grass, giant reed, Bermuda grass, Johnson grasses or turf grass, millet, hemp, bananas, poplars, *eucalyptus* trees and conifers. Of interest are plants grown for energy production, so called energy crops, such as broadleaf plants like alfalfa, hemp, Jerusalem artichoke and grasses such as sorghum, switchgrass, Johnson grass and the likes. Thus, the described materials and methods are useful for modifying biomass characteristics, such as characteristics of biomass renewable energy source plants. A biomass renewable energy source plant is a plant having or producing material (either raw or processed) that comprises stored solar energy that can be converted to fuel. In general terms, such plants comprise dedicated energy crops as well as agricultural and woody plants. Examples of biomass renewable energy source plants include: switchgrass, elephant grass, giant chinese silver grass, energycane, giant reed (also known as wild cane), tall fescue, bermuda grass, sorghum, napier grass, also known as uganda grass, triticale, rye, winter wheat, shrub poplar, shrub willow, big bluestem, reed canary grass and corn.

Homologues Encompassed by the Invention

It is known in the art that one or more amino acids in a sequence can be substituted with other amino acid(s), the charge and polarity of which are similar to that of the

substituted amino acid, i.e. a conservative amino acid substitution, resulting in a biologically/functionally silent change. Conservative substitutes for an amino acid within the polypeptide sequence can be selected from other members of the class to which the amino acid belongs. Amino acids can be divided into the following four groups: (1) acidic (negatively charged) amino acids, such as aspartic acid and glutamic acid; (2) basic (positively charged) amino acids, such as arginine, histidine, and lysine; (3) neutral polar amino acids, such as serine, threonine, tyrosine, asparagine, and glutamine; and (4) neutral nonpolar (hydrophobic) amino acids such as glycine, alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan, cysteine, and methionine.

Nucleic acid molecules of the present invention can comprise sequences that differ from those encoding a protein or fragment thereof selected from the group consisting of SEQ ID NOs. 80, 99, 106, 123, 132, 146, 154 and 172, respectively, due to the fact that the different nucleic acid sequence encodes a protein having one or more conservative amino acid changes.

Biologically functional equivalents of the polypeptides, or fragments thereof, of the present invention can have about 10 or fewer conservative amino acid changes, more preferably about 7 or fewer conservative amino acid changes, and most preferably about 5 or fewer conservative amino acid changes. In a preferred embodiment of the present invention, the polypeptide has between about 5 and about 500 conservative changes, more preferably between about 10 and about 300 conservative changes, even more preferably between about 25 and about 150 conservative changes, and most preferably between about 5 and about 25 conservative changes or between 1 and about 5 conservative changes.

Identification of Useful Nucleic Acid Molecules and their Corresponding Nucleotide Sequences

The nucleic acid molecules, and nucleotide sequences thereof, of the present invention were identified by use of a variety of screens that are predictive of nucleotide sequences that provide plants with improved vegetative growth, growth rate, and/or biomass under saline conditions. One or more of the following screens were, therefore, utilized to identify the nucleotide (and amino acid) sequences of the present invention.

The present invention is further exemplified by the following examples. The examples are not intended to in any way limit the scope of the present application and its uses.

6. Experiments Confirming the Usefulness of the Polynucleotides and Polypeptides of the Invention

General Protocols

Agrobacterium-Mediated Transformation of *Arabidopsis*

Host Plants and Transgenes: Wild-type *Arabidopsis thaliana* Wassilewskija (WS) plants are transformed with Ti plasmids containing nucleic acid sequences to be expressed, as noted in the respective examples, in the sense orientation relative to the 35S promoter in a Ti plasmid. A Ti plasmid vector useful for these constructs, CRS 338, contains the Ceres-constructed, plant selectable marker gene phosphinothricin acetyltransferase (PAT), which confers herbicide resistance to transformed plants.

Ten independently transformed events are typically selected and evaluated for their qualitative phenotype in the T₁ generation.

Preparation of Soil Mixture: 24 L Sunshine Mix #5 soil (Sun Gro Horticulture, Ltd., Bellevue, Wash.) is mixed with 16 L Therm-O-Rock vermiculite (Therm-O-Rock West, Inc., Chandler, Ariz.) in a cement mixer to make a 60:40 soil mixture. To the soil mixture is added 2 Tbsp Marathon 1% granules (Hummert, Earth City, Mo.), 3 Tbsp OSMO-COTE® 14-14-14 (Hummert, Earth City, Mo.) and 1 Tbsp Peters fertilizer 20-20-20 (J. R. Peters, Inc., Allentown, Pa.), which are first added to 3 gallons of water and then added to the soil and mixed thoroughly. Generally, 4-inch diameter pots are filled with soil mixture. Pots are then covered with 8-inch squares of nylon netting.

Planting: Using a 60 mL syringe, 35 mL of the seed mixture is aspirated. 25 drops are added to each pot. Clear propagation domes are placed on top of the pots that are then placed under 55% shade cloth and subirrigated by adding 1

inch of water.
Plant Maintenance: 3 to 4 days after planting, lids and shade cloth are removed. Plants are watered as needed. After 7-10 days, pots are thinned to 20 plants per pot using forceps. After 2 weeks, all plants are subirrigated with Peters fertilizer at a rate of 1 Tsp per gallon of water. When bolts are about 5-10 cm long, they are clipped between the first node and the base of stem to induce secondary bolts. Dipping infiltration is performed 6 to 7 days after clipping.

Preparation of *Agrobacterium*: To 150 mL fresh YEB is added 0.1 mL each of carbenicillin, spectinomycin and rifampicin (each at 100 mg/ml stock concentration). *Agrobacterium* starter blocks are obtained (96-well block with *Agrobacterium* cultures grown to an OD₆₀₀ of approximately 1.0) and inoculated one culture vessel per construct by transferring 1 mL from appropriate well in the starter block. Cultures are then incubated with shaking at 27° C. Cultures are spun down after attaining an OD₆₀₀ of approximately 1.0 (about 24 hours). 200 mL infiltration media is added to resuspend *Agrobacterium* pellets. Infiltration media is prepared by adding 2.2 g MS salts, 50 g sucrose, and 5 µL 2 mg/ml benzylaminopurine to 900 ml water.

Dipping Infiltration: The pots are inverted and submerged for 5 minutes so that the aerial portion of the plant is in the *Agrobacterium* suspension. Plants are allowed to grow normally and seed is collected.

High-throughput Phenotypic Screening of Misexpression Mutants: Seed is evenly dispersed into water-saturated soil in pots and placed into a dark 4° C. cooler for two nights to promote uniform germination. Pots are then removed from the cooler and covered with 55% shade cloth for 4-5 days. Cotyledons are fully expanded at this stage. FINALE® (Sanofi Aventis, Paris, France) is sprayed on plants (3 ml FINALE® diluted into 48 oz. water) and repeated every 3-4 days until only transformants remain.

Screening: Screening is routinely performed by high-salt agar plate assay and also by high-salt soil assay. Traits assessed in high-salt conditions include: seedling area, photosynthesis efficiency, salt growth index, and regeneration ability.

Seedling area: the total leaf area of a young plant about 2 weeks old.

Photosynthesis efficiency (Fv/Fm): Seedling photosynthetic efficiency, or electron transport via photosystem II, is estimated by the relationship between Fm, the maximum fluorescence signal and the variable fluorescence, Fv. Here, a reduction in the optimum quantum yield (Fv/Fm) indicates stress, and so can be used to monitor the performance of transgenic plants compared to non-transgenic plants under salt stress conditions.

Salt growth index=seedling area×photosynthesis efficiency (Fv/Fm).

PCR was used to amplify the DNA insert in one randomly chosen T₂ plant. This PCR product was then sequenced to confirm the sequence in the plants.

Assessing Tolerance to Salt Stress: Initially, independently transformed plant lines are selected and qualitatively evaluated for their tolerance to salt stress in the T₁ generation. The transformed lines that qualitatively show the strongest tolerance to salt stress in the T₁ generation are selected for further evaluation in the T₂ and T₃ generations. This evaluation involves sowing seeds from the selected transformed plant lines on MS agar plates containing either 100 mM or 150 mM NaCl and incubating the seeds for 5 to 14 days to allow for germination and growth.

Calculating SGI: After germination and growth, seedling area and photosynthesis efficiency of transformed lines and a wild-type control are determined. From these measure-

ments, the Salt Growth Index (SGI) is calculated and compared between wild-type and transformed seedlings. The SGI calculation is made by averaging seedling area and photosynthesis efficiency measurements taken from two replicates of 36 seedlings for each transformed line and a wild-type control and performing a t-test.

Determining Transgene Copy Number: T₂ generation transformed plants are tested on BASTA™ plates in order to determine the transgene copy number of each transformed line. A BASTA™ resistant:BASTA™ sensitive segregation ratio of 3:1 generally indicates one copy of the transgene.

Results:

The following Examples provide information for polynucleotides and their encoded polypeptides useful for increasing tolerance to salt stress. Enhanced salt tolerance gives the opportunity to grow crops in saline conditions without stunted growth and diminished yields due to salt-induced ion imbalance, disruption of water homeostasis, inhibition of metabolism, damage to membranes, and/or cell death. The ability to grow crops in saline conditions would result in an overall expansion of arable land and increased output of land currently marginally productive due to elevated salinity

Example 1: ME03807 (Ceres Clone 8686; SEQ ID No. 79)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter operatively linked to Ceres Clone 8686. Two transformed lines, ME03807-02 and ME03807-03, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 1-1). Their tolerance to 150 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated that ME03807-02 contains two copies of the transgene and that ME03807-03 carries one copy of the transgene.

TABLE 1-1

Prevalidation assay of ME03807 salt tolerance as compared to wild-type Ws			
	WS Wild-type	ME03807-02	ME03807-03
Mean*	0.0268	0.0397	0.0506
Standard Error	0.0006	0.0041	0.0038

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plates containing 150 mM NaCl, ME03807-02 and ME03807-03 transgenic plants showed significantly increased seedling area and SGI relative to non-transgenic plants. As shown in Table 1-2, the T₂-generation SGI value for ME03807-02 seedlings increased by 74.4% while ME03807-03 seedlings increased by 87.6% compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 134.2% for ME03807-02 and 141.8% for ME03807-03. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress is a result of the ectopic expression of Ceres Clone 8686 in the ME03807 transformant lines.

TABLE 1-2

Validation assay of ME03807 salt stress tolerance in two generations									
ME Events	SGI* of transgenics			SGI of pooled non-transgenics			t-Test		% of SGI increase
	Avg	SE	N	Avg	SE	N	value	t _{0.05}	
ME03807-02T ₂	0.952	0.126	32	0.546	0.087	24	2.66	1.68	74.4
ME03807-03T ₂	0.604	0.047	24	0.322	0.065	13	3.51	1.70	87.6
ME03807-02T ₃	0.965	0.111	19	0.412	0.031	11	5.95	1.70	134.2
ME03807-03T ₃	1.064	0.104	42	0.440	0.028	16	9.60	1.68	141.8

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 8686 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type WS seedlings.

The protein encoded by Ceres Clone 8686 is a 255-amino-acid putative cyclase (Susstrunk et al. (1998) *Mol*

Microbiol, 30(1):33-46 and Kang et al. (1999) *Microbiology*, 145:1161-72. Cyclase is a large gene family that includes adenylyl cyclase, which converts ATP to cAMP. cAMP is an important signal molecule that is involved in signal transduction which conveys signals from a plasma membrane receptor to cytosol cascades. The ME03807 transgene is more closely related to cyclase enzymes that are involved in antibiotic synthesis.

Example 2: ME00774 (Ceres Clone 2767; SEQ ID No. 131)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 32449 promoter (SEQ ID No. 77) and Ceres Clone 2767. Two transformed lines, ME00774-03 and ME00774-04, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 2-1). Their tolerance to 150 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant:BASTA™ sensitive) indicated that ME00774-03 contains two copies of the transgene and that ME00774-04 carries one copy of the transgene.

TABLE 2-1

Prevalidation assay of ME00774 salt tolerance as compared to wild-type Ws						
	Ws wild-type	ME00774-01	ME00774-02	ME00774-03	ME00774-04	ME00774-05
Mean*	0.0286	0.0313	0.0333	0.0468	0.0384	0.0343
Std Error	0.0006	0.0015	0.0019	0.0037	0.0026	0.0024

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plates containing 150 mM NaCl, ME00774-03 and ME00774-04 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 2-2, the T₂-generation SGI value for ME00774-03 seedlings increased by 41.8% while ME00774-04 seedlings increased by 379.4% compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 315.1% for ME00774-03 and 551.8% for ME00774-04. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 2767 in the ME00774 transformant lines.

TABLE 2-2

Validation assay of ME00774 on salt tolerance in two generations									
ME Events	SGI* of transgenics			SGI of pooled non-transgenics			t-Test		% of SGI increase
	Avg	SE	N	Avg	SE	N	value	t _{0.05}	
ME00774-03T ₂	1.462	0.122	51	1.031	0.127	18	2.45	1.67	41.8
ME00774-04T ₂	0.954	0.072	20	0.199	0.03	10	9.78	1.70	379.4
ME00774-03T ₃	1.598	0.081	48	0.385	0.05	23	12.79	1.67	315.1
ME00774-04T ₃	1.082	0.091	20	0.166	0.032	16	9.52	1.70	551.8

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Clone 2767 under the control of the 32449 promoter enhances tolerance to salt stress.

Ceres Clone 2767 encodes a 154-amino-acid protein that belongs to a universal stress protein family (Kerk et al. (2003) *Plant Physiol.* 131 (3): 1209-19). The USP superfamily has its members conserved in bacteria, archaea, and eukaryotes. The expression of USP genes in *E. coli* is induced by a large variety of environmental insults. The *uspA* gene plays an important role for *E. coli* to survive in cellular growth arrest, but the molecular mechanism of the gene function is not known yet (Nachin et al. (2005) *J Bacteriol* 187(18):6265-72). In *Arabidopsis*, there are 44 family members of USP. However, their function has not been characterized yet (Kerk et al. 2003). A rice homolog, OsUsp1, has been found to be induced by submergence and ethylene (Sauter et al. (2002) *J Exp Bot* 53(379):2325-31).

The identification of an AtUsp gene in a salt screen suggests that the *Arabidopsis* USP family members may play a similar role in stress tolerance as observed in *E. coli*.

Example 3: ME0146 (Ceres Clone 16403; SEQ ID No. 145)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres Clone 16403. Two transformed lines, ME01468-01 and ME01468-04, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 3-1). Their tolerance to 100 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated ME01468-01 and ME01468-04 transformed lines each carry one copy of the transgene.

TABLE 3-1

Prevalidation assay of ME00774 salt tolerance as compared to wild-type Ws					
	Ws Wild-type	ME01468-01	ME01468-02	ME01468-03	ME01468-04
Mean*	0.0268	0.0424	0.0312	0.0215	0.0395
Standard Error	0.0006	0.0032	0.0018	0.0027	0.0031

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plates containing 100 mM NaCl, ME01468-01 and ME01468-04 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 3-1, the T₂-generation SGI value for ME01468-01 seedlings increased by 23.7% while ME01468-04 seedlings increased by 39.3% compared

ME01468-04. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 16403 in the ME01468 transformant lines.

TABLE 3-2

Validation assay of ME01468 on salt tolerance in two generations										
ME	Events	SGI* of			SGI of pooled			t-Test		% of SGI increase
		transgenics			non-transgenics			t-	t _{0.05}	
		Avg	SE	N	Avg	SE	N	value	t _{0.05}	
ME01468-01T ₂		3.842	0.146	39	3.105	0.307	29	2.162	1.67	23.7
ME01468-04T ₂		3.143	0.179	35	2.256	0.261	32	2.795	1.67	39.3
ME01468-01T ₃		5.939	0.416	33	3.233	0.296	37	5.293	1.67	83.7
ME01468-04T ₃		7.508	0.524	13	4.186	0.469	21	4.719	1.70	79.4

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 16403 under the control of the 35S promoter enhances tolerance to high salt stress.

Ceres Clone 16403 encodes a 238-amino-acid calcium-binding protein that also shows similarity to an oxygen evolving complex from rice (Sanchez-Barrena et al. (2005) *J Mol Biol.* 345(5):1253-64). It is worth noting that SOS3, an important gene involved in salt tolerance, has been molecularly characterized as a Ca⁺⁺ binding protein.

Example 4: ME02064 (Ceres Clone 375578; SEQ ID No.98)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres Clone 375578. Three transformed lines, ME02064-01 and ME02064-03, ME02064-04, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 4-1). Their tolerance to 150 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated ME02064-01 and ME02064-03, ME02064-04 transformed lines each carry one copy of the transgene.

TABLE 4-1

Prevalidation assay of ME02064 salt tolerance as compared to wild-type Ws						
	Ws Wild-type	ME02064-01	ME02064-02	ME02064-03	ME02064-04	ME02064-05
Mean*	0.0359	0.0435	0.0346	0.0441	0.0438	0.0305
Standard Error	0.0016	0.0048	0.004	0.0041	0.0035	0.0019

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 83.7% for ME01468-01 and 79.4% for

When grown on MS agar plates containing 150 mM NaCl, ME02064-01 and ME02064-03, ME02064-04 transgenic

plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 4-2, the T₂-generation SGI value for ME02064-01 seedlings increased by 110% while ME02064-03 seedlings increased by 131% and ME02064-04 seedlings increased by 72% compared to non-transgenic control seedlings. In the T₃

generation, the SGI increase was 43% for ME02064-01, 47% for ME02064-03, and 64% for ME02064-04. The differences between transgenic and non-transgenic seedlings are statistically significant, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 375578 in the ME02064 transformant lines.

TABLE 4-2

Validation assay of ME02064 on salt tolerance in two generations									
ME	SGI* of			SGI of pooled			t-Test		% of
	transgenics			non-transgenics			t-	SGI	
Events	Avg	SE	N	Avg	SE	N	value	t _{0.05}	increase
ME02064-01-T ₂	2.057	0.249	12	0.977	0.205	17	3.35	1.70	110.5
ME02064-03-T ₂	2.237	0.371	5	0.968	0.140	24	3.20	1.70	131.1
ME02064-04-T ₂	1.810	0.146	14	1.055	0.135	13	3.81	1.70	71.6
ME02064-01-T ₃	2.438	0.170	21	1.708	0.289	9	2.18	1.70	42.7
ME02064-03-T ₃	2.837	0.257	20	1.927	0.271	14	2.43	1.70	47.2
ME02064-04-T ₃	2.770	0.318	16	1.688	0.188	19	2.93	1.70	64.1

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 375578 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Ceres Clone 375578 encodes a 311-amino-acid protein that belongs to the calmodulin binding family (Sanchez-Barrena et al. (2005) *J Mol Biol.* 345(5):1253-64). Ca⁺⁺ homeostasis is an important signaling cascade in abiotic and biotic resistance. A critical gene, SOS3, involved in salt tolerance has been previously identified to be a Ca⁺⁺ binding protein. Understanding the connection between SOS3 and the transgene in ME02064 will help to better engineer resistance to salt stress.

Example 5: ME04074 (Ceres Clone 105319; SEQ ID No. 105)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres Clone 105319. Two transformed lines, ME04074-02 and ME04074-05, showed the strongest qualitative tolerance

to salt stress in a prevalidation assay (Table 5-1). Their tolerance to 150 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTATM resistant: BASTATM sensitive) indicate ME04074-02 and ME04074-05 transformed lines each carry one copy of the transgene.

TABLE 5-1

Prevalidation assay of ME04074 salt tolerance as compared to wild-type Ws						
	Ws Wild-type	ME04074-01	ME04074-02	ME04074-03	ME04074-04	ME04074-05
Mean*	0.0301	0.0332	0.0423	0.0351	0.039	0.0448
Standard Error	0.0032	0.0027	0.0033	0.0026	0.0025	0.0027

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plates containing 150 mM NaCl, ME04074-02 and ME04074-05 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 5-2, the T₂-generation SGI value for ME04074-02 seedlings increased by 40.6% while ME04074-05 seedlings increased by 52.2% compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 18.5% for ME04074-02 and 60.6% for ME04074-05. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 105319 in the ME04074 transformant lines.

TABLE 5-2

Validation assay of ME04074 on salt tolerance in two generations									
ME	SGI* of			SGI of pooled			t-Test		% of
	transgenics			non-transgenics			t-	SGI	
Events	Avg	SE	N	Avg	SE	N	value	t _{0.05}	increase
ME04074-02-T ₂	2.432	0.212	23	1.730	0.155	40	2.68	1.67	40.6
ME04074-05-T ₂	2.707	0.212	26	1.778	0.171	38	3.41	1.67	52.2
ME04074-02-T ₃	2.257	0.156	34	1.905	0.190	34	1.43	1.67	18.5
ME04074-05-T ₃	2.851	0.158	32	1.775	0.147	52	4.98	1.67	60.6

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 105319 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

The protein encoded by Ceres Clone 105319 encodes a putative shikimate cyclase (Griffen et al. (1995) *DNA Seq* 5(3):195-197). The enzyme has ATP binding activity and catalyzes the fifth step in the biosynthesis of aromatic amino acids from chorismate. The protein is found in bacteria, fungi and plants. How this protein is involved in stress response is not yet known. However, aromatic acids, such as L-phenylalanine, are important substrates for the phenylpropanoid biosynthesis pathway, which produces many compounds related to stress responses.

Example 6: ME02907 (Ceres Clone 29658; SEQ ID No.122)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and

Ceres Clone 29658. Three transformed lines, ME02907-01, ME02907-03 and ME02907-05, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 6-1). Their tolerance to 150 mM NaCl was further evaluated in a validation assay using ME02907-03 and ME02907-05 for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated ME02907-03 and ME02907-05 transformed lines each carry one copy of the transgene.

TABLE 6-1

Prevalidation assay of ME02907 salt tolerance as compared to wild-type Ws					
	Ws Wild-type	ME02907-01	ME02907-03	ME02907-04	ME02907-05
Mean*	0.0268	0.034483	0.0315	0.0224	0.0368
Standard Error	0.0006	0.002016	0.0029	0.0031	0.0039

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plates containing 150 mM NaCl, ME02907-03 and ME02907-05 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 6-2, the T₂-generation SGI value for ME02907-03 seedlings increased by 59% while ME02907-05 seedlings increased by 67% as compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 110% for ME02907-03 and 99% for ME02907-05. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 29658 in the ME02907 transformant lines.

TABLE 6-2

Validation assay of ME02907 on salt tolerance in two generations									
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test		% of SGI increase
	Avg	SE	N	Avg	SE	N	value	t _{0.05}	
ME02907-03-T ₂	1.252	0.115	31	0.787	0.121	18	2.79	1.68	59.1
ME02907-05-T ₂	1.235	0.120	34	0.738	0.100	28	3.18	1.67	67.3
ME02907-03-T ₃	1.039	0.100	26	0.495	0.023	15	7.40	1.69	109.9
ME02907-05-T ₃	1.157	0.064	37	0.582	0.070	17	7.53	1.70	98.8

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 29658 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

The protein encoded by Ceres Clone 29658 is a putative calmodulin. Sanchez-Barrena et al. *J Mol Biol.* 345(5): 1253-64. Ca⁺⁺-mediated signaling is critical in salt tolerance. SOS3 has been demonstrated to confer salt tolerance in *Arabidopsis* and it has Ca⁺⁺-binding activity.

Example 7: ME00199 (Ceres Clone 3964; SEQ ID No. 153)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 32499 promoter and Ceres Clone 3964. Two transformed lines, ME00199-02 and ME00199-03, showed the strongest qualitative tolerance to salt stress in a prevalidation assay (Table 7-1). Their tolerance to 100 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated ME00199-02 and ME00199-03 transformed lines each carry one copy of the transgene.

TABLE 7-1

Prevalidation assay of ME00199 salt tolerance as compared to wild-type Ws				
	Ws wild-type	ME00199-01-01	ME00199-02-01	ME00199-03-01
Mean*	0.0268	0.0244	0.0401	0.0307
Standard Error	0.0006	0.0025	0.0052	0.0037

*Average seedling area of 36 plants grown on MS agar plates containing 150 mM NaCl for 14 days

When grown on MS agar plate containing 100 mM NaCl, ME00199-02 and ME00199-03 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 7-2, the SGI value of T₂-generation ME00199-02 seedlings increased by 106.6% and the SGI value of T₂-generation ME00199-03 seedlings increased by 48.2% as compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 174.3% for ME00199-02 and 205.9% for ME00199-03. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 3964 in the ME00199 transformant lines.

TABLE 7-2

Validation assay of ME00199 on salt tolerance in two generations										
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test		% of SGI increase	
	Avg	SE	N	Avg	SE	N	value	t _{0.05}		
ME00199-02T ₃	4.6025	0.3400	43	2.2277	0.2159	28	5.90	1.67	106.6	
ME00199-03T ₃	3.8795	0.3444	40	2.6182	0.3855	28	2.44	1.67	48.2	
ME00199-02T ₄	6.8743	0.5132	45	2.5058	0.5904	12	5.58	1.68	174.3	
ME00199-03T ₄	7.4472	0.7392	30	2.4343	0.5283	15	5.52	1.68	205.9	

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

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Summary of Results:

Ectopic expression of Ceres Clone 3964 under the control of the 32499 promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

The protein encoded by Ceres Clone 3964 is a putative steroid sulfotransferase (351 AA).

Example 8: ME09814 (Ceres Clone 965405; SEQ ID No. 171)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres Clone 965405. Two transformed lines, ME09814-01 and ME09814-02, showed the strongest qualitative tolerance to salt stress in a prevalidation assay. Their tolerance to 100 mM NaCl was further evaluated in a validation assay for two generations. Segregation ratios (BASTA™ resistant: BASTA™ sensitive) indicated ME09814-01 and ME09814-02 transformed lines each carry one copy of the transgene originated from *Brassica napus* subsp. *napus* (canola).

Grown on MS agar plates containing 100 mM NaCl, ME09814-01 and ME09814-02 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 8-1, the SGI value of T2-generation ME09814-01 seedlings increased by 29% and the SGI value of T2-generation ME09814-02 seedlings increased by 69% as compared to non-transgenic control seedlings. In the T₃ generation, the SGI increase was 80% for ME09814-01 and 49% for ME09814-02. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 965405 in the ME09814 transgenic lines.

TABLE 8-1

Validation assay of ME09814 on salt tolerance in two generations									
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test		% of SGI increase
	Avg	SE	N	Avg	SE	N	value	t _{0.05}	
ME09814-01T ₂	2.6841	0.2346	37	2.0812	0.1830	34	2.03	1.67	29.0
ME09814-02T ₂	2.6985	0.2438	32	1.5942	0.1909	38	3.57	1.67	69.3
ME09814-01T ₃	3.0664	0.2934	29	1.6996	0.1724	42	4.02	1.67	80.4
ME09814-02T ₃	2.6878	0.2350	36	1.8087	0.1743	34	3.00	1.67	48.6

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 965405 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

The protein encoded by Ceres Clone 965405 is an unknown protein.

Example 9: ME07361 (Ceres Clone 5367; SEQ ID NO: 245)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres Clone 5367. Ceres Clone 5367 is a functional homolog of Ceres clone 965405.

Grown on MS agar plates containing 100 mM NaCl, ME07361-04 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 9-1, the SGI value of T2-generation ME07361-03 seedlings increased by 30.34% and the SGI

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value of T2-generation ME07361-04 seedlings increased by 52% as compared to non-transgenic control seedlings. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres Clone 5367 in the ME07361 transgenic lines.

TABLE 9-1

Results of ME07361 on salt tolerance assay in T2 generations								
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test	SGI increase
	Avg	SE	N	Avg	SE	N		
ME07361-01	0.89	0.103	16	0.89	0.105	20	0.489	-0.45%
ME07361-02	1.30	0.160	17	1.22	0.132	18	0.357	06.29%
ME07361-03	1.58	0.195	21	1.21	0.151	15	0.073	30.34%
ME07361-04	1.98	0.369	15	1.30	0.145	21	0.049	52.00%

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Ceres Clone 5367 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Example 10: ME09594 (Annot ID 566551; SEQ ID NO: 290)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Annot ID 566551. Annot ID 566551 is a functional homolog of Ceres clone 965405.

Grown on MS agar plates containing 100 mM NaCl, ME09594-03 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 10-1, the SGI value of T2-generation ME09594-03 seedlings increased by 60.09% as compared to non-transgenic control seedlings. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Annot ID 566551 in the ME09594 transgenic lines.

TABLE 10-1

Results of ME09594 on salt tolerance assay in T2/T3 generation								
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test p-value	SGI increase
	Avg	SE	N	Avg	SE	N		
ME09594-01	2.17	0.357	19	2.36	0.352	16	0.357	-7.87%
ME09594-02-99	1.83	1.109	4	1.72	0.252	24	0.463	6.20%
ME09594-03	2.32	0.380	24	1.45	0.280	9	0.038	60.09%
ME09594-04-99	0.71	0.110	16	0.79	0.082	17	0.288	-9.82%
ME09594-05	2.38	0.465	13	2.69	0.392	21	0.305	-11.66%

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Summary of Results:

Ectopic expression of Annot ID 566551 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Example 11: ME23428 (Annot ID 842118; SEQ ID NO: 289)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Annot ID 842118. Annot ID 842118 is a functional homolog of Ceres clone 29658.

Grown on MS agar plates containing 100 mM NaCl, ME23428-02 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 11-1, the SGI value of T2-generation ME23428-02 seedlings increased by 81.77% as compared to non-transgenic control seedlings. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Annot ID 842118 in the ME23428 transgenic lines.

TABLE 11-1

Results of ME23428 on salt tolerance assay in T2 generation								
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test p-value	SGI increase
	Avg	SE	N	Avg	SE	N		
ME23428-01	1.26	0.166	9	1.76	0.283	26	0.069	-28.36%
ME23428-02	1.17	0.134	18	0.65	0.139	11	0.005	81.77%
ME23428-03	0.63	0.036	13	0.64	0.039	19	0.386	-2.43%
ME23428-04	0.93	0.108	18	0.84	0.222	13	0.371	9.72%
ME23428-05	0.99	0.144	19	0.97	0.166	14	0.466	1.96%

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Transgenic plants of ME23428-02 showed significant better tolerance to high salt than pooled non-transgenics.

Summary of Results:

Ectopic expression of Annot ID 842118 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Example 12: ME24903 (Clone 295570; SEQ ID NO: 275)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres clone 295570. Ceres clone 295570 is a functional homolog of Ceres clone 8686.

Grown on MS agar plates containing 100 mM NaCl, ME24903-04, ME24903-05, ME24903-07 and ME24903-09 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 12-1, the SGI value of T2-generation ME24903-04 seedlings increased by 68.42%, the SGI value of T2-generation ME24903-05 seedlings increased by 55.99%, the SGI value of T2-generation ME24903-07 seedlings increased by 140.73% and the SGI value of T2-generation ME24903-09 seedlings increased by 121.46% as compared to non-transgenic control seedlings. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the enhanced tolerance to salt stress was a result of the ectopic expression of Ceres clone 295570 in the ME24903 transgenic lines.

TABLE 12-1

Results of ME24903 on salt tolerance assay in T2 generation								
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test p-value	SGI increase
	Avg	SE	N	Avg	SE	N		
ME24903-04	0.97	0.141	19	0.58	0.091	15	0.0123	68.42%
ME24903-05	1.72	0.221	18	1.10	0.160	17	0.0153	55.99%
ME24903-07	1.51	0.229	21	0.63	0.112	12	0.0008	140.73%
ME24903-08	0.89	0.087	18	0.79	0.208	12	0.3241	13.22%
ME24903-09	1.86	0.303	14	0.84	0.104	20	0.0016	121.46%

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Transgenic plants of ME24903-04, -5, -7 and -09 showed significant better tolerance to high salt than pooled non-transgenics.

Summary of Results:

Ectopic expression of Ceres clone 295570 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Example 13: ME10681 (Clone 335348; SEQ ID NO: 314)

Wild-type *Arabidopsis thaliana* Wassilewskija was transformed with a Ti plasmid carrying the 35S promoter and Ceres clone 335348. Ceres clone 335348 is a functional homolog of Ceres clone 375578.

Grown on MS agar plates containing 100 mM NaCl, ME10681-02, ME10681-04, and ME10681-05 transgenic plants showed significantly greater seedling area and SGI relative to non-transgenic plants. As shown in Table 13-1, the SGI value of T2-generation, the SGI value of T2-generation ME10681-02 seedlings increased by 119.17%, the SGI value of T2-generation ME10681-04 seedlings increased by 113.51% and the SGI value of T2-generation ME10681-05 seedlings increased by 103.98% as compared to non-transgenic control seedlings. The differences between transgenic and non-transgenic seedlings are statistically significant under the t-test, and clearly demonstrate that the

enhanced tolerance to salt stress was a result of the ectopic expression of Ceres clone 335348 in the ME10681 transgenic lines.

TABLE 13-1

Results of ME10681 on salt tolerance assay in T2 generation								
ME	SGI* of transgenics			SGI of pooled non-transgenics			t-Test	SGI increase
	Avg	SE	N	Avg	SE	N	p-value	
ME10681-01	3.87	0.6837	9	2.78	0.4324	24	0.0940	39.17%
ME10681-02	4.13	0.3354	25	1.89	0.5752	11	0.0009	119.17%
ME10681-04	6.22	0.4787	12	2.91	0.5671	15	7.66E-05	113.51%
ME10681-05	5.25	0.3916	20	2.57	0.6140	15	0.0004	103.98%

*SGI (Salt Growth Index) = seedling area × Fv/Fm (photosynthesis efficiency)

Transgenic plants of ME10681-02, -04 and -05 showed significant better tolerance to high salt than pooled non-transgenics.

Summary of Results:

Ectopic expression of Ceres clone 335348 under the control of the 35S promoter enhances tolerance to salt stress that causes necrotic lesions and stunted growth in wild-type Ws seedlings.

Example 14: Determination of Functional Homolog Sequences

The sequences described in the above Examples are utilized as query sequences to identify functional homologs of the query sequences and, together with those sequences, are utilized to define consensus sequences for a given group of query and functional homolog sequences. Query sequences and their corresponding functional homolog sequences are aligned to illustrate conserved amino acid consensus sequences that contain frequently occurring amino acid residues at particular positions in the aligned sequences, as shown in FIGS. 1-9.

A subject sequence is considered a functional homolog of a query sequence if the subject and query sequences encode proteins having a similar function and/or activity. A process known as Reciprocal BLAST (Rivera et al. (1998) *Proc. Natl Acad. Sci. USA* 95:6239-6244) is used to identify potential functional homolog sequences from databases consisting of all available public and proprietary peptide sequences, including NR from NCBI and peptide translations from Ceres clones.

Before starting a Reciprocal BLAST process, a specific query polypeptide is searched against all peptides from its source species using BLAST in order to identify polypeptides having sequence identity of 80% or greater to the query polypeptide and an alignment length of 85% or greater along the shorter sequence in the alignment. The query polypeptide and any of the aforementioned identified polypeptides are designated as a cluster.

The main Reciprocal BLAST process consists of two rounds of BLAST searches; forward search and reverse search. In the forward search step, a query polypeptide sequence, "polypeptide A," from source species S^d is BLASTed against all protein sequences from a species of interest. Top hits are determined using an E-value cutoff of 10⁻⁵ and an identity cutoff of 35%. Among the top hits, the sequence having the lowest E-value is designated as the best hit, and considered a potential functional homolog. Any other top hit that had a sequence identity of 80% or greater to the best hit or to the original query polypeptide is considered a potential functional homolog as well. This process is repeated for all species of interest.

In the reverse search round, the top hits identified in the forward search from all species are used to perform a BLAST search against all protein or polypeptide sequences

from the source species S^d. A top hit from the forward search that returned a polypeptide from the aforementioned cluster as its best hit is also considered as a potential functional homolog.

Functional homologs are identified by manual inspection of potential functional homolog sequences. Representative functional homologs are shown in FIGS. 1-9. The Figures represents a grouping of a query sequence aligned with the corresponding identified functional homolog subject sequences. Query sequences and their corresponding functional homolog sequences are aligned to identify conserved amino acids and to determine a consensus sequence that contains a frequently occurring amino acid residue at particular positions in the aligned sequences, as shown in FIGS. 1-9.

An HMM was made based on SEQ ID NOs: 80, 84, 85, 90, 92, 93 and 95, aligned in FIG. 1. When fit to the HMM, SEQ ID NOs: 80, 81, 82, 83, 84, 85, 86, 87, 89, 90, 91, 92, 93, 95, 97, 182, 184, 186, 188, 190, 191, and 192 gave HMM bit scores of 576.8, 394.8, 231.4, 382.2, 523.7, 632.7, 39.3, 409.6, 386.4, 569.7, 551.4, 621.4, 635.3, 633.5, 573.9, 543.4, 594.6546.7, 493.1, 613.4, and 635.3, respectively.

An HMM was made based on SEQ ID NOs: 100, 252, 298, 301, 302, 303 and 312 aligned in FIG. 2. When fit to the HMM, SEQ ID NOs: 100, 102, 103, 104, 252, 298, 300, 301, 302, 303 and 312 gave HMM bit scores of 1315.8, 208.1, 118.5, 173.9, 1272.1, 1235.9, 635.2, 1206.4, 225.6, 1212.9 and 1233.4, respectively.

An HMM was made based on SEQ ID NOs: 106, 107, 112, 113, 114 and 115, aligned in FIG. 3. When fit to the HMM, SEQ ID NOs: 106, 107, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 121, 194, 196, 197, 198 and 200 gave HMM bit scores of 593.7, 487.6, 238.4, 113.8, 492.6, 536.1, 524.8, 289.4, 624.9, 288.2, 476.4, 282.4, 489.3, 588.8, 545.8, 503.3, 491.5, 486, 504.9, respectively.

An HMM was made based on SEQ ID NOs: 123, 125, 126, 127, 128, 129 and 130, aligned in FIG. 4. When fit to the HMM, SEQ ID NOs: 123, 125, 126, 127, 128, 129, 130, 270 and 284 gave HMM bit scores of 390.1, 327.9, 392.3, 396.5, 394.8, 393.7, 323.8, 330.6 and 235.5, respectively.

An HMM was made based on SEQ ID NOs: 132, 134, 139, 142 and 143, aligned in FIG. 5. When fit to the HMM, SEQ ID NOs: 132, 134, 136, 138, 139, 141, 142, 143 and 144 gave HMM bit scores of 343.8, 454.5, 208, 197, 388.2, 144.1, 319.9, 375.2 and 295.2, respectively.

An HMM was made based on SEQ ID NOs: 146, 147, 149, 151 and 152, aligned in FIG. 6. When fit to the HMM, SEQ ID NOs: 146, 147, 149, 150, 151, 152, 202, 204 and 206 gave HMM bit scores of 593.1, 602.9, 570.8, 355.3, 633.9, 570.8, 369.3, 474.7 and 357.4, respectively.

An HMM was made based on SEQ ID NOs: 154, 157, 160, 161, 163, 164, 168, and 169, aligned in FIG. 7. When fit to the HMM, SEQ ID NOs: 154, 155, 157, 159, 160, 161,

162, 163, 164, 165, 166, 167, 168, 169, 170, 274, 278, 282, 286 and 288 gave HMM bit scores of 894.1, 719.9, 901.3, 801.4, 747, 810.2, 692.7, 748.7, 779.9, 656.3, 603.6, 485.1, 816.9, 634.5, 149, 498, 510, 584.3, 455.2 and 670.6, respectively.

An HMM was made based on SEQ ID NOs: 172, 173, 174, 175, 176, 177 and 179, aligned in FIG. 8. When fit to the HMM, SEQ ID NOs: 172, 173, 174, 175, 176, 177, 179, 208, 210, 212 and 213 gave HMM bit scores of 533.9, 542, 570.8, 559.9, 547.5, 474.8, 531.3, 414.3, 447.1, 358.5 and 344, respectively.

An HMM was made based on SEQ ID NOs: 304, 305, 306, 307, 308, 309, 310 and 311, aligned in FIG. 9. When fit to the HMM, SEQ ID NOs: 100, 102, 103, 104, 252, 298, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311 and 312 gave HMM bit scores of 418.9, 208.1, 118.5, 173.9, 407.6, 490.5, 156.9, 461, 462, 469.6, 462, 461, 406.7, 462, 469.6, 418.9, 490.5 and 493.3, 493.3 respectively.

Useful polypeptides of the invention include each of the sequences and corresponding functional homolog sequences shown in the Figures and/or the Sequence Listing, as well as polypeptides belonging to the corresponding consensus sequence families as delineated by HMMs. In different embodiments, consensus sequence families have HMM bit score lower limits as about 50%, 60%, 70%, 80%, 90%, or 95% of any of the HMM bit scores of the family members presented in this application. In some embodiments the lower HMM bit score limits correspond approximately to the HMM bit score of any of the family members disclosed in this application. A sequence that has an HMM bit score of 20 means that it has a 95% likelihood of belonging to the consensus sequence defined by a particular HMM. Alternative HMM bit scores that are useful for the current invention are 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450 and 500.

The present invention further encompasses nucleotides that encode the above described polypeptides, as well as the complements thereof, and including alternatives thereof based upon the degeneracy of the genetic code.

The invention being thus described, it will be apparent to one of ordinary skill in the art that various modifications of the materials and methods for practicing the invention can be made. Such modifications are to be considered within the scope of the invention as defined by the following claims.

The following references are cited in the Specification. Each of the references from the patent and periodical literature cited herein is hereby expressly incorporated in its entirety by such citation.

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SEQUENCE LISTING

The patent contains a lengthy sequence listing. A copy of the sequence listing is available in electronic form from the USPTO web site (<https://seqdata.uspto.gov/?pageRequest=docDetail&DocID=US11655479B2>). An electronic copy of the sequence listing will also be available from the USPTO upon request and payment of the fee set forth in 37 CFR 1.19(b)(3).

What is claimed is:

1. A plant cell transformed with a recombinant nucleic acid molecule comprising a promoter operably linked to a nucleic acid, wherein the promoter and the nucleic acid are heterologous to each other, wherein said nucleic acid comprises a nucleotide sequence selected from the group consisting of:

(a) a nucleotide sequence that encodes a protein comprising an amino acid sequence that is at least 95% identical to the amino acid sequence of SEQ ID NO:132 and having activity of the SEQ ID NO: 132;

(b) a nucleotide sequence that encodes a protein that comprises the amino acid sequence of SEQ ID NO:132;

(c) a nucleotide sequence comprising the polynucleotide sequence of SEQ ID NO:131 and encoding the protein as set forth in SEQ ID NO: 132; and

(d) a nucleotide sequence comprising a nucleotide sequence that is at least 95% identical to the polynucleotide sequence of SEQ ID NO:131 and encodes a protein having activity of the SEQ ID NO: 132,

and wherein a transformed plant obtained from the transformed plant cell expresses said protein and exhibits increased tolerance to salinity as compared to a control plant of the same species lacking said recombinant nucleic acid molecule and grown under identical conditions.

2. A transgenic plant comprising the transformed plant cell of claim 1, wherein the transgenic plant exhibits increased tolerance to salinity as compared to a control plant of the same species grown under identical conditions and that does not comprise the recombinant nucleic acid molecule.

3. A progeny of the transformed plant of claim 2, wherein said progeny is transformed with the recombinant nucleic acid molecule and has increased tolerance to salinity as compared to the control plant.

4. A transgenic seed from a transgenic plant according to claim 2 which comprises the recombinant nucleic acid molecule.

5. A transgenic vegetative tissue from a transgenic plant according to claim 2, wherein the transgenic vegetative tissue comprises the recombinant nucleic acid molecule.

6. A food product comprising a transgenic vegetative tissue from a transgenic plant according to claim 2, wherein the food product comprises the recombinant nucleic acid molecule.

7. A feed product comprising a transgenic vegetative tissue from a transgenic plant according to claim 2, wherein the feed product comprises the recombinant nucleic acid molecule.

8. A product comprising a transgenic vegetative tissue from a transgenic plant according to claim 2 used for the conversion into fuel or chemical feedstocks, wherein the product comprises the recombinant nucleic acid molecule.

9. The transgenic plant of claim 2, wherein the nucleotide sequence encodes a protein that comprises the amino acid sequence of SEQ ID NO:132.

10. The transgenic plant of claim 2, wherein the nucleotide sequence encodes a protein comprising an amino acid sequence that is at least 95% identical to the amino acid sequence of SEQ ID NO:132 and having activity of the SEQ ID NO: 132.

11. The transgenic plant of claim 2, wherein the nucleotide sequence comprising the polynucleotide sequence of SEQ ID NO:131 and encoding the protein of SEQ ID NO: 132.

12. The transgenic plant of claim 2, wherein the nucleotide sequence is at least 95% identical to the polynucleotide sequence of SEQ ID NO:131 and encodes a protein having activity of SEQ ID NO: 132.

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